Control ENGINEERING

INSTRUMENTATION AND AUTOMATIC CONTROL SYSTEMS

A McGRAW-HILL PUBLICATION

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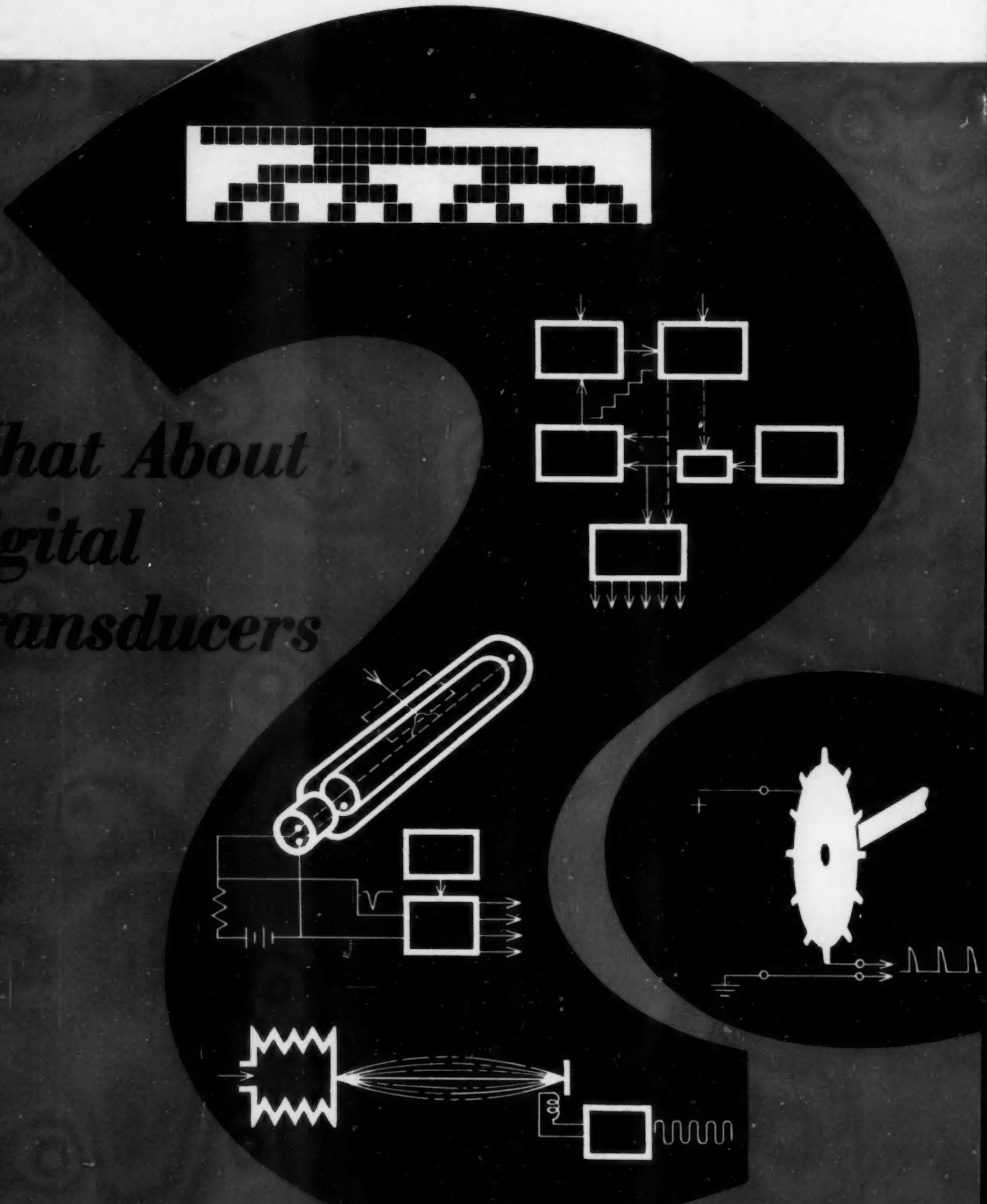
JULY 1958



What About Digital Transducers

Control
ENGINEERING

JULY 1958 VOL. 5 NO. 7

Published for engineers and technical management men who are responsible for the design, application and test of instrumentation and automatic control systems

Continued on next page

Control ENGINEERING

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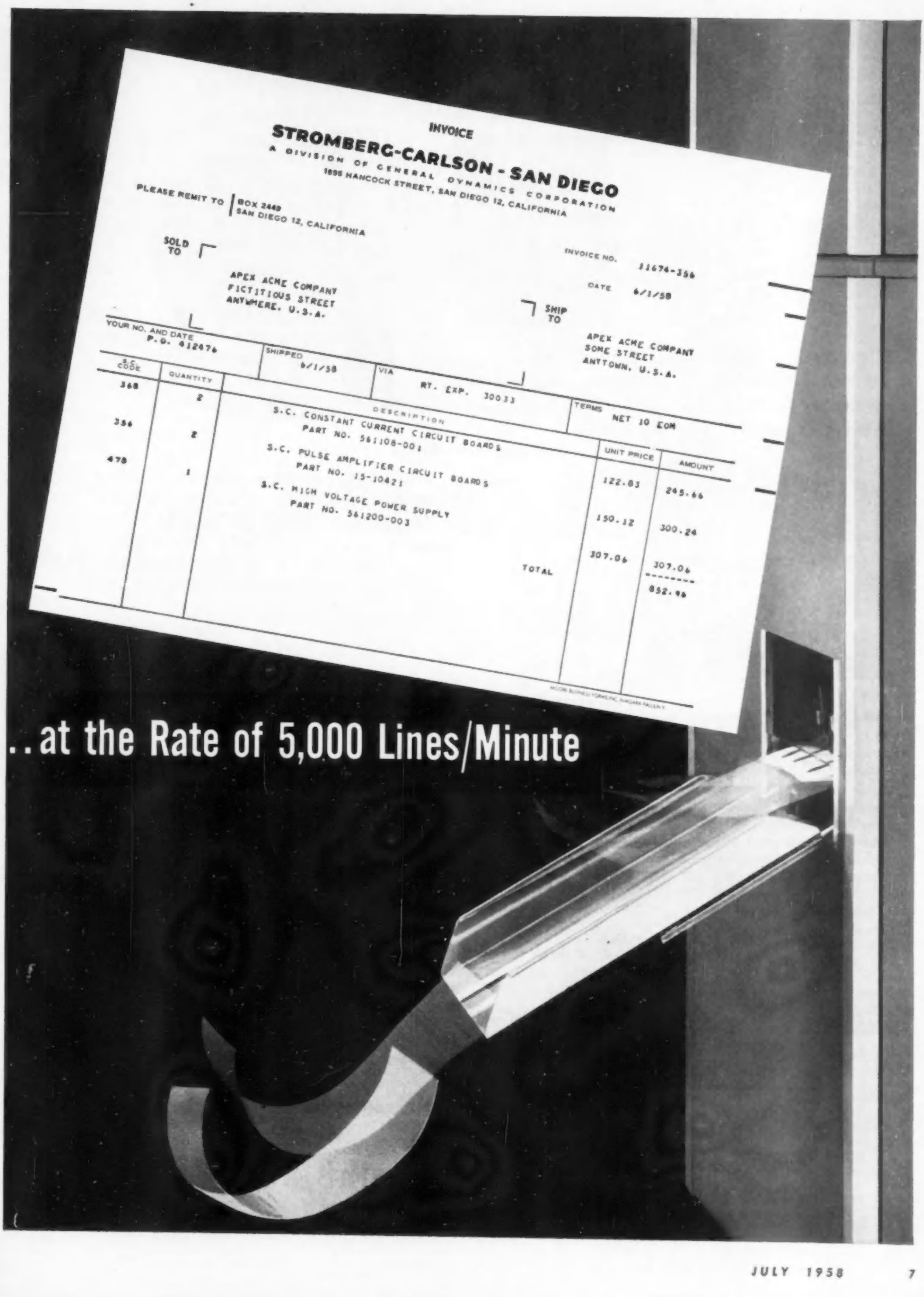
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SHOPTALK

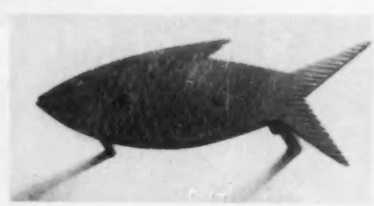
From sextant to inertial navigation

John Slater (coauthor with D. E. Wilcox of "How Precise are Inertial Components?", page 86) is more at home with inertial navigation systems nowadays than he is with the bubble sextant he's shown holding here. After graduating from MIT in 1932, John first consulted in the field of applied physics, then in 1947 joined North American Aviation. Now, as staff specialist in guidance engineering, he is responsible for keeping Autometics in the forefront by consulting and directing research programs in inertial navigation and guidance systems.

CtE editors contribute

CtE is well-represented in the recently published *Control Engineer's Handbook* (McGraw-Hill Book Co.; editor: John Truxal of Brooklyn Polytechnic Institute). Assistant Editor Ed Kompass authored the section on digital computers in control, and Managing Editor By Ledgerwood coauthored (with Sid Davis) the sections on electrical actuators and tachometers, clutches and brakes, and mechanical control components. Many CtE contributors also supplied material for this "first" handbook tailored for control engineers.

Recognition for our art director



Jack Gordon—who earns his keep making CONTROL ENGINEERING look pretty—recently received recognition as a prominent collector of American folk art. The Cincinnati Art Museum purchased 13 pieces from Jack's collection, including pottery, drawings, and wrought-iron craft, for display in a new wing of American rooms that will be opened this fall. The accompanying photo shows one of the most interesting exhibits: a wrought-iron fish that was originally used as an axe socket on a Conestoga wagon in the late 18th century.

Kazuto Togino starts rolling

CtE's Japanese correspondent is beginning to make his influence felt. In this month's *Industry's Pulse*, page 69, he gives forth with his views on the status of automatic control in Japan. Future issues will include other articles as well as news items on control in Japan, all aimed at keeping the CONTROL ENGINEERING reader up-to-date on developments in this important area.

FEEDBACK

PROBLEM FORUM

The controversy over acceleration-switching electrohydraulic valves is far from over. An article by W. I. Harris in the April 1958 issue reporting on experiences in using acceleration-switching valves generated diverse comments from all over the country. The two published here reflect the substance of all others.

Submit your comments on the technical accuracy and completeness of articles published in CONTROL ENGINEERING. If accepted for publication, they will earn you a bonus in legal tender. To other readers will accrue a bonus in technical information. You earn while they learn. Ed.

To the Editor—

You may recall that I was project engineer at the Moog Valve Co. in charge of all acceleration-switching valve test, design, and production for almost two years. With this in mind, I wish to convey a few points of disagreement with the article by W. I. Harris of McDonnell Aircraft in the April issue of CtE.

Tests have been run which do confirm the fact that a well-built acceleration-switching valve is an integrator. If an integrator for a feedback system is defined as a device which generates the time integral of the measured error signal and actuates an output member so as to eliminate the error, then the acceleration-switching valve is truly an integrator. It will operate against loads up to the equivalent of its system pressure and instantly reduce the position error (due to the imposed load) to an immeasurable quantity by integrating the error signal. The reduction of slope in the Bode plot and the apparent "break or corner" frequency as referred to by Harris is actually a nonlinear effect which is dependent on much more than just the valve rated flow. It is certainly a variable which can be controlled by the design and construction technique used in assembly of the torque motor.

We built 30 identical acceleration-switching valves in one production run and found the τ to vary all the way from 0.1 to 1.0 sec on the batch. This is a variable which in large part can be controlled by careful assembly and adjustment of the torque motor. Probably there are other variables which also affect τ.

Now a few words about accelera-

(Continued bottom next page)

To the Editor—

We obtain the transfer function of an acceleration-switching valve indirectly from the frequency response of a closed-loop servo system of which it is a part. The parameters which describe the performance of the various components of this servo are all accurately known, with the exception of those which describe the performance of the valve. We adjust the servo input signal amplitude to maintain a reasonably constant oil flow as the input signal frequency is varied. An alternate method is to obtain the valve's transfer function indirectly from the measured transfer function between the error voltage and the servo output position. However, if there is even a relatively small amount of deviation from purely sinusoidal output motion, the error signal becomes sufficiently distorted to make data reduction difficult. For this reason, we prefer the first method.

Early in our switching-valve work we found that we could not explain the closed-loop frequency responses obtained from our servos if the assumption of pure integrator action of the valve was made. Further work seems to have confirmed our suspicion that a first-order lag is a more accurate representation of the switching valve. As a matter of fact, W. Seamone of the Applied Physics Laboratory (Johns Hopkins University) has developed a method of predicting the time constant with reasonable accuracy from a knowledge of the physical parameters of the valve.

Of course, the use of a first-order transfer function to represent the performance of any type of valve is a gross oversimplification. A considerable amount of work has been done to

derive a describing function for nonlinearities in proportional-flow valves. The resulting expressions are quite complicated. The task of deriving an analytical description of a switching valve is considerably more difficult. To the writer's knowledge, it has never been done. Nevertheless, it is useful to have a simplified transfer function to use for first-cut design work. Representing a switching valve by a first-order lag fulfills this need since one is able to predict closed-loop servo performance with reasonable accuracy on this basis.

When reporting the reasons for failing to obtain reduced prices for switching valves, the writer was merely acting as a reporter. The statements given to the writer by various vendors were merely repeated. The very small dimensions assigned by the writer to the flapper-nozzle circuit pertained to the spacing between the flapper and the nozzles. In proportional-flow valves, the diameter of the upstream orifices is generally an order of magnitude greater. In our high-temperature test, we experienced a large degree of contamination—perhaps more than "considerable." The static null was essentially unaffected by the orifice clogging. However, when sinusoidal input signals were applied to the servo, the null was observed to shift as a function of input signal frequency. This can only be explained by assuming that the spool velocity was considerably greater in one direction than the other—an indication of upstream orifice clogging.

W. I. Harris
Missile Engineering Div.
McDonnell Aircraft Corp.
St. Louis, Mo.

(Continued from preceding page)
tion-switching valve cost. Customers still specify narrow limits for valve linearity and leakage. As long as they do, the null of the spool-bushing combination and the fit between the spool and bushing will have to be carefully controlled, as in "linear" valves. This costs money. Careful assembly and adjustment of the torque motor is necessary in order to assure a low "break" frequency and balanced valve operation over wide ranges of temperature, oil pressures, switching frequencies, and current amplitudes. Possibly a new acceleration-switching valve design could be made which would reduce some of the cost of the parts; the valves presently being made are modifications of the "linear" valves.

One other factor which can reduce the cost would be for the customer to determine the input signal current

FEEDBACK

amplitude and the switching frequency he intends to operate at before writing his purchase specification. The large amount of testing required up to this time because of failure to follow this suggestion has resulted in the acceleration-switching valve cost staying equivalent to the cost of a standard valve. Many of the valves being made are required to operate over a 50 percent current amplitude variation and a 50 percent switching frequency change because the customer does not know how he will use the valve.

The customer requirement of dynamically measuring linearity of spool-orifice gain could be waived. As people become more familiar with the acceleration-switching technique and learn more about it by actually working with the hardware, I believe a set of meaningful production tests will be determined which will insure the customer getting the product he wants in a shorter time and at a reduced cost.

Stephen A. Murtaugh
Systems Synthesis Dept.
Cornell Aeronautical Laboratory, Inc.
Buffalo, N. Y.

Information, please—"hot" application

To the Editor—

We are interested in applying hydraulic, electric and pneumatic servo systems to equipment handling radioactive materials and, of course, we want to learn all we can of the problems introduced by radiation environments.

Can you tell us where we can get information on the application of servo components in "hot" labs? We understand that radiation has some unusual effects on organic hydraulic fluids, for example.

Frank M. Foster
Plant Products Corp.
Cincinnati, Ohio

Contact E. See Day Jr., General Electric Co., 761 Building, Richland, Wash., chairman of the Instrument Society of America RP-25 recommended practices subcommittee on materials for use in instruments used in radiation service. For information on hydraulic systems in radiation service, try these:

George Keller, Autonetics Div., North American Aviation, Inc., 9150 East Imperial Highway, Downey, Calif.

C. H. Cannon, Lockheed Aircraft Corp., Georgia Div., Marietta, Ga.

FEEDBACK

W. E. Mayhew, Republic Aviation Corp., Farmingdale, Long Island, N. Y. Ed.

**Information, please—
computer literature**

To the Editor—

I had from you some time ago an abstract of "Review of Input and Output Equipment used in Computing Systems," presented at a joint conference in March 1953. Was this type of conference ever followed up by others and did you publish the proceedings?

I presume these are normally published by the AIEE but in any case, I should like your sterling prices and earliest possible delivery.

W. H. Brooks
Newman Industries, Ltd.
Bristol, England

The Proceedings of the Eastern Joint Computer Conference of December 1956 and December 1957 are available at $3 a copy. Proceedings of the 1957 Conference are in the mails now. Copies can be obtained by writing to: Institute of Radio Engineers, One East 79th St., New York, N. Y. "Review of Input and Output Equipment Used in Computing Systems" is no longer available. Ed.

**Information, please—
contouring control**

To the Editor—

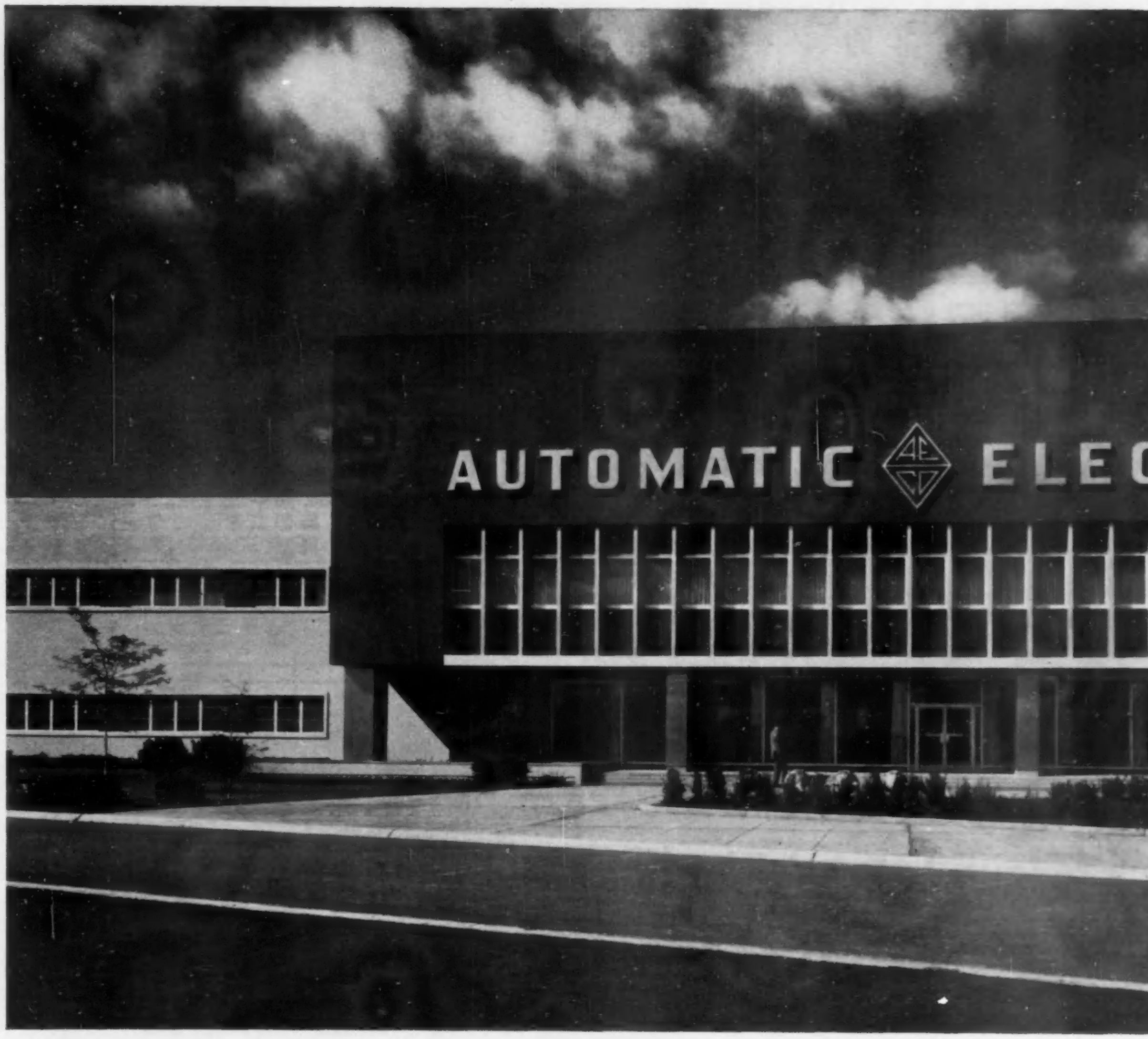
I read the condensation of your article, "Numerical Controls in Production", in the February 1958 issue of *Factory Management and Maintenance* magazine, with great interest. However, our particular problem is "roughing out" forging dies in our die shop. This operation apparently falls into the "contour control" category, which was not covered in the condensation.

Would you kindly supply any information you have available, or forward the names of manufacturers who are active in this phase of the field.

Walter J. Martin
J. H. Williams & Co.
Buffalo, N. Y.

Contact:
- Cincinnati Milling Machine Co.
- Kearney & Trecker Machine Tool Co., Milwaukee, Wis.
- Morey Machine Co., New York City.
- Giddings & Lewis Machine Tool Co., Fond du Lac, Wis.

Ed.



What can this new 35-acre plant

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Walk through this magnificent new plant—and you'll see the world's most modern, most complete facilities for making relays and stepping switches.

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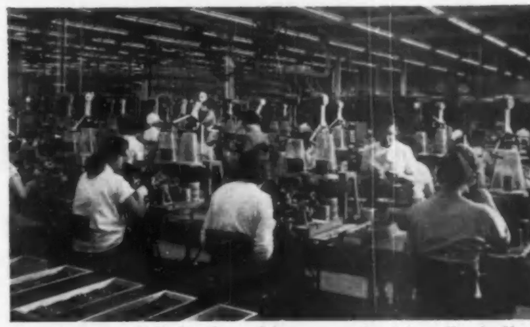
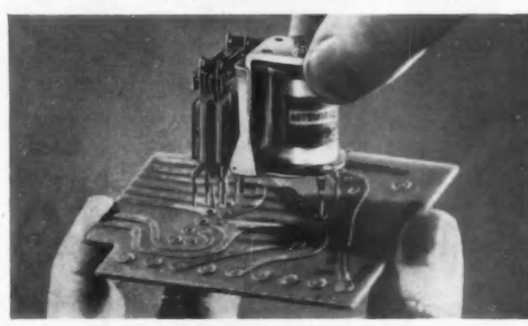
Tour this plant and you'll see the uncommon care we take to produce relays and switches of superior quality. You'll see why Automatic Electric has earned the reputation "world's highest standard." You'll see why our relays *set performance records of 200 to 400 million operations without a failure!*



Spacious, well-lighted working areas in this coil-winding department at Automatic Electric's new plant are typical of conditions throughout the more than one million square feet of floor space devoted to production operations.

Filming high-speed rotary switches to study operations in slow motion. Basic research program of our laboratories extends into all areas of remote control by electronic and electromechanical means. Equipment includes devices for conducting vibration, life and environmental studies, and a completely equipped transistor laboratory.



New miniature relays for printed circuits. New Series SQPC Relays fill a multitude of uses with dependability and long life (120 million operations or more). Features include efficient magnetic design, permanently welded contacts, "stay-put" contact springs and many other advantages found in all Automatic Electric Relays.

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Bernard Levine

backs the components approach

Like many other Cooper Union men, Bernie Levine graduated just in time (1944) to practically grow up in the precision components business. For years, he has been scrambling hard to come up with components that will fit within the black boxes designed by his systems-oriented customers in the military services. Today he does his scrambling for Norden Ketay Corp., where he is vice-president and general manager of the Precision Components Div.

Levine has no quarrel with the systems people. In fact, he is awed by the way in which the systems approach has conquered fantastic problems in fire control and guidance. But he feels that components engineers are too hard pressed to meet deadlines to develop ideal hardware. "We've had to resort many times to derating and improvisation," he says, "to produce the special components that make a system work. As a result, the state of the components art advances slowly. Certainly, no one can dispute that scientific advances in recent years have been lopsidedly in favor of systems."

What Bernie Levine dreams of is a chance to jump way out in front of his friends in the systems business. He hopes the components industry will one day soon have on the shelf standard units that will meet any foreseeable requirements from systems engineers. An example of such a "universal" component? Well, says Levine, a ½-in.-diam synchro rated at 600 C, 2,500 hours will satisfy any demand for many, many years to come. And, Levine stresses, such an item must not be a freak. It must come as a result of a real breakthrough in component technology, so that it can be producible in quantity at practical cost.

Levine not only thinks such a breakthrough is possible, but is willing to bet on it. For some time he and his engineers have been looking at "oblique" approaches to component design. That is why he's ecstatic about Frankford Arsenal's recent decision to back him for a study of these oblique approaches. Levine can quickly name at least 10 other manufacturers of servo components that share his belief about the feasibility of a breakthrough.

But support for their R&D will be slow in coming from military agencies, most of whose budgets are earmarked for systems—not components. It is one thing to get an appropriation for the design of a system for a shot at the moon and quite another to win sponsorship for research on the unglamorous nuts and bolts needed to make the system work. Levine laments about the fact that he has never had a chance to study a Russian synchro—perhaps because the military is unwilling to break into any Soviet black boxes they happen to come by.

In his Commack, L. I. office, Levine admits he signs a few checks now and then, just as does any other general manager. But he still holds the engineering reins too, although it means stretching out his workday a bit longer. Relaxation comes at home with his wife Anne, daughter Linda, son Jerry, and a hi-fi set; on the golf course; and during his 45-min car ride to and from work (". . . my only chance to catch up on the news").

There will be more time to relax when the "ultimate" components are on the shelf. But in the meantime, Bernie Levine has a lot of black boxes to fill. (For one project, see page 26.)

Computer Market Shifts

Supply and demand picture for computers in missile and aircraft work has changed sharply. Visitors to the Western Joint Computer Conference couldn't help but notice that user engineers were being a lot more discriminating in their examination of equipment.

That's a major change from 18 months ago. At that time a missile contractor might rent or buy whatever equipment was available and be glad to get it. But today engineers know a lot more about the kind of problems they're facing, so they specify computer requirements more carefully and more narrowly.

As a result, customers are shopping around to find the computer with the specific capability and capacity for the specific type of problem they want solved.

In addition, word heard at WJCC indicated that improved models of existing computers weren't selling as well as expected. Those companies that have fared best are the ones that have placed completely new developments on the market, developments that make it easier for users to make more effective use of their computers.

New Guidance For Bomarc

The Air Force's surface-to-air defense missile Bomarc has two guidance systems. A radio-controlled system puts the missile in the target area, then a terminal system (believed to use infrared sensors) aims Bomarc on a collision course. Now Bomarc is getting a new advanced ground control system. Last month Westinghouse Electric Corp., which is building the terminal system, was awarded a $10 million contract to develop a system that would:

▶ Control the missile over considerably longer ranges.

▶ Permit automatic radar tracking of targets before and after launching.

▶ Permit tracking of more targets simultaneously.

▶ Reduce size to make the ground control system more easily portable.

Initial tests of the Bomarc have been conducted at Cape Canaveral.

How the Soviets Boost Production

Eighty percent of the increase in Soviet production up to 1965 will result from increased productivity. That's what Iosif Kuzmin, vice-chairman of the USSR Council of Ministers, told a conference on mechanization and automation held in the Kremlin recently.

Claiming the "world's fastest rate of growth of labor productivity" for Russia, Kuzmin cited these plans:

▶ The metal working industry will have in use over 1,400 automatic transfer machines by 1965; the woodworking industry, 350.

▶ Tests of the first completely automatic locomotive control (requires no human interference) are under way.

▶ An automatic machine has been developed to determine optimum exploitation patterns for gas and oil.

▶ Five times as much automation equipment will be produced in 1965 as in 1958.

Kuzmin pointed out that today USSR is producing 20 percent of the world's manufactured goods, compared to only three precent in 1917.

TRANSIENTS IN CONTROL

British electronics manufacturer EMI Electronics, Ltd. has built a wire guidance system for automatic control of powered trolleys and trucks in warehouses. Current coursing through the wire sets up a magnetic field which is detected by sensing coils mounted on the front of the trolley. (Apparently the system is similar to Guidematic, developed by U.S.'s Barrett-Cravens.)

•

Automatic testing equipment has been developed by Lockheed Aircraft Corp.'s Georgia Div. to speed testing of B-47 wiring harnesses. The new equipment gives the 120-wire harness a three-way check in 3 min; it used to take 75. Automatic testing is more realistic because a 24-volt system is used instead of the 3-volt current formerly employed.

•

Still another automatic mail sorter has gone to work. At Washington, D. C.'s city post office, an electromechanical semi-automatic machine is sorting 250,000 pieces of mail a day. Built by the Bell Telephone Mfg. Co. of Antwerp (a subsidiary of International Telephone & Telegraph), the machine has six operators; each sits at a key board and punches out mail's destination.

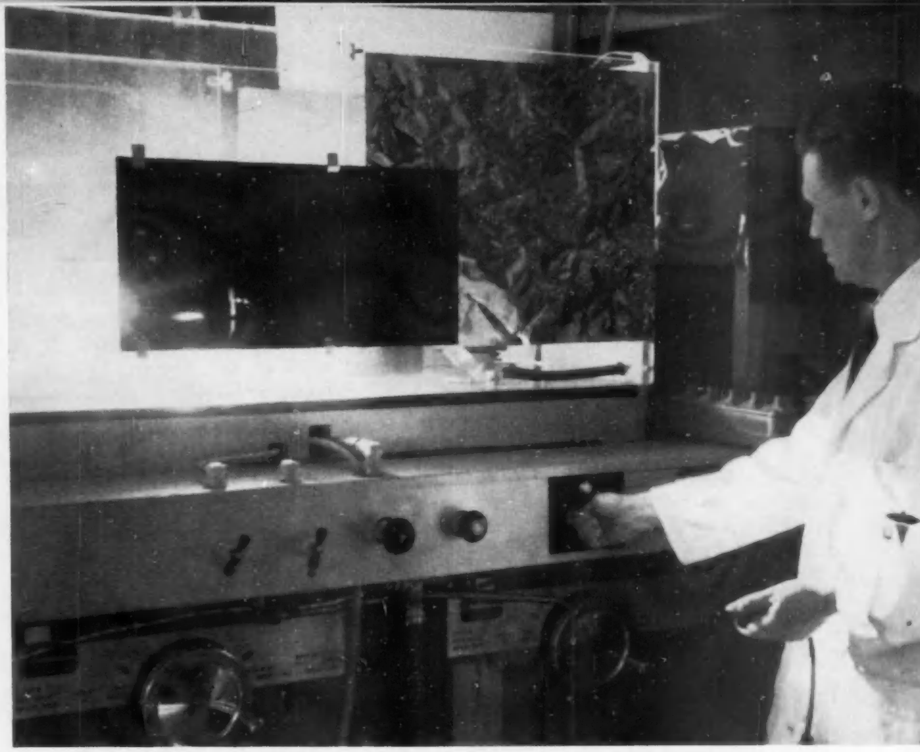
•

British IRBM is being built by DeHavilland Propellers, Ltd. The rocket power plant will be supplied by Rolls-Royce, and the guidance system by Sperry Gyroscope Co.

•

Two machine tool builders are adapting available numerical control systems to their machines. Cleerman Machine Tool Corp. is using the General Electric point-to-point positioning system (CtE, Jan. '58, p. 92) on a layout drilling machine. Morey Machinery Co. has put Stromberg-Carlson's Electronic Control Systems Div. Digimatic (CtE, Feb. '58, p. 115) on a Morey A-50 machine to cut continuously circular contours.

Here's what's going on at one of the Air Force's basic research centers. Projects range from developing high-speed computer equipment to studying rocket guidance—all aimed at conquering space travel.



Plasma jet reaches temperatures as high as 25,000 deg F to simulate conditions on missile nose cones.

Aeronautical Research Laboratory

Probes Space Flight for the Future

Because its mission is the future, the U.S. Air Force's Aeronautical Research Laboratory has shifted research emphasis from aerodynamic flight to space technology. And to speed the conquest of space, ARL moved, in May, into a spanking new $3,787,000 Physical Sciences Laboratory* at Wright-Patterson Air Force Base. Studies under way at the new facilities leave little doubt about Air Force interest in space flight. Here's a run-down on a few of the unclassified projects of particular interest to control engineers:

▶ Development of a high-speed electronic printer capable of printing 10,800 lines per minute, for use with high-speed digital computers.

▶ Research on solar radiation, aimed at least in two directions: studying cadmium sulfide crystals to improve efficiency of solar batteries, and determining how to use solar energy to decompose water into oxygen and hydrogen (so the gases can be used in a fuel cell).

▶ Simulation on the biggest (500 operational amplifiers) analog computer ever built at one time. This REAC has automatic programming, automatic checking of patchboards, and automatic identification of runs on recorder printouts.

▶ Light amplification systems extending limitations of the eye from 1/1,000,000 foot-lambert to 1/100,000,000 foot-lambert; sights are set on 1/10,000,000,000 levels.

▶ Development of an electronic camera to photograph explosions and plasma experiments; camera can take 16 pictures in 100 microsec.

▶ Development of new chemicals with unusual properties. Typical example: the perarylated silanes. Developed primarily as a high-temperature lubricant—they can lubricate at temperatures as high as 1,000 deg F—the silanes have properties that make them useful in nuclear instrumentation, too.

▶ Studies with hypersonic wind tunnels and shock tubes to learn fundamentals of high-temperature, high-speed flight.

▶ Efforts to simplify rocket guidance by developing techniques for displacing rocket-engine thrust vector without gimbaling the entire engine.

Obviously, the efforts of ARL span the entire field of science. Three branches cope with the systems concept and computational aspects of space research. These three, the only portion of ARL not located in the new building, are: systems dynamics and digital and analog computation.

In the systems branch, scientists formulate and investigate fundamental problems, primarily using simulation techniques. Two typical examples: determining what direction and speed a nonhoming rocket must have at the point of departure in space; and determining the best trajectory for a homing missile to follow in an attack on a bomber aircraft. Solution of such problems are then handled by one of the computational groups.

• **Digital studies**—The digital computation branch uses a Univac 1103, has just added a Univac 1103A, which

* *Located just a half-mile from the plain on which the Wright brothers did some of their basic studies on the first airplane.*

should start operating this month. But in addition to operating such equipment, the digital branch also conducts research in computing techniques and equipment. One such effort has resulted in a high-speed electronic printer that prints out 10,800 lines per minute. Built by Radiation, Inc., the printer costs about \$40,000. Each line contains 12 digits; line capacity could be expanded to 90 digits by adding electronic components (at a cost of about \$25,000).

Just recently, ARL set up a new group to probe the application of computers in space vehicles. This new computer research branch's job is to study environmental effects on computers during space travel.

• **Hi-fi simulation**—Costing as much as the new building, ARL's new REAC analog computer is the last word in simulation equipment. Its component accuracy—an order of magnitude better than most machines—makes engineers talk of high-fidelity simulation of air-weapons systems.

One unusual characteristic of this computer is its high degree of automaticity. The components can be programmed off the machine; and ARL has a separate checking device that automatically reads out what connections have been made by the plugboard. Another example of automatic operation: inputs are automatically programmed on tape.

By paralleling capacitors, the computer simplifies checking frequency lag. One switch automatically slows down the problem to half-speed so engineers can determine if servo lags are introducing errors. And at the start of the run, the computer tests the recorders, then prints out on the record the location of zero, scale being used, electrical zero, and the paper speed—all automatically.

The analog branch also has a separate universal checker that dynamically tests every computer element.

• **Improving on the cat-eye**—In the physics laboratory, studies are under way on light amplification, an area that has application today as well as in future space vehicles. ARL has improved the "cat-eye" system developed, so the human eye can detect illumination at levels below 1/1,000,000 foot-lambert. Two devices being evaluated are worthy of mention. The video storage reproducer eliminates TV noise at high amplification by storing 90 percent of the pattern, thus producing the picture periodically instead of continuously. The dynamic background compensator can pick up only those objects which are in motion. Its use, is to spot moving targets normally not visible.

Still another physics project is the development of a high-speed electronic camera with no moving parts. Capable of taking up to 16 pictures in less than 100 microsec, this device combines an optical and an electronic lens system. Light rays are first focused by a conventional lens onto a surface which is sensitive to photo electrons. Electrons emitted are focused electronically onto a phosphorescent screen at the end of the 16-in. camera barrel. Position of the image is then moved to different places on the film by changing a magnetic field.

• **New molecules**—In the chemistry laboratories, ARL scientists are developing new molecules with unusual properties. One unique compound has been made by swirling silicon atoms through aryls (chemical ring groups) to produce perarylated silanes. Among the advantages of the silanes are: thermal stability, good electrical insulating properties at high temperatures, and stability under nuclear radiation.

Developed as a high-temperature lubricant (up to 1,000 deg F), solid silane shows promise for nuclear detection because of its property of scintillating under radiation. Actually, silane permits making two important nuclear measurements with the same material: first, how much radiation fell on the material over a period of time, and second, how much radiation is currently hitting it.

• **Plasma for high temperatures**—A number of branches of ARL are studying the problems of exceptionally high temperatures raised by missile and space flights. There are a variety of experiments under way with rapid heating. One technique of developing high temperatures (up to 25,000 deg C) involves plasmas, highly ionized gases. But the lack of good high-temperature measuring instruments remains a problem.

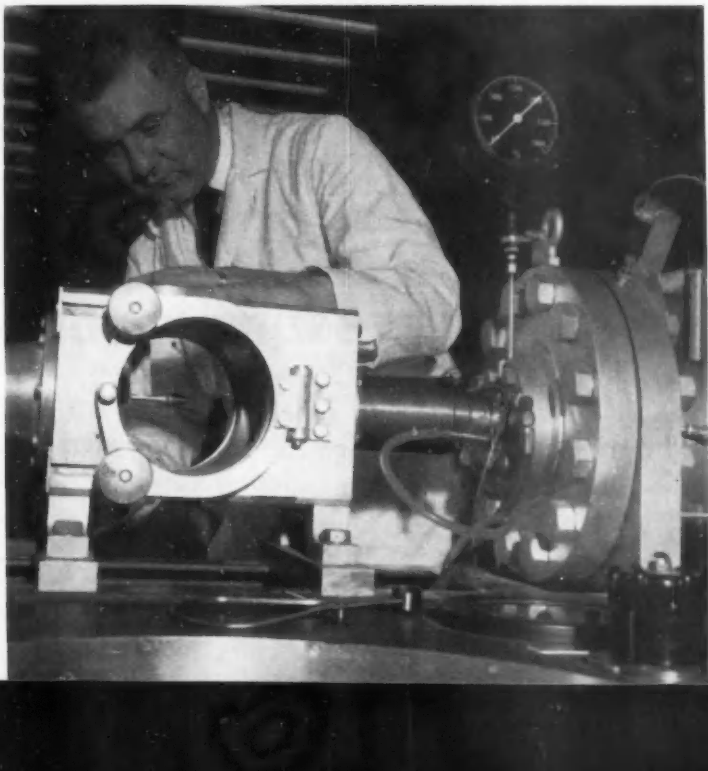
Also widely used in ARL studies are the hypersonic wind tunnel and shock tubes. Hypersonic is usually defined as meaning speed in excess of Mach 5.

ARL has also developed a hypersonic test vehicle, a two-stage rocket that reaches speeds of 10,000 to 11,000 mph. As accessory equipment, the laboratory has built a miniaturized tape recorder, about the size of a grapefruit, to ride along with the rocket. It can record 16 separate channels for about 60 sec. A radioactive material located in the base of the recorder locates the tiny recorder after a test (usually conducted at Holoman AFB in New Mexico).

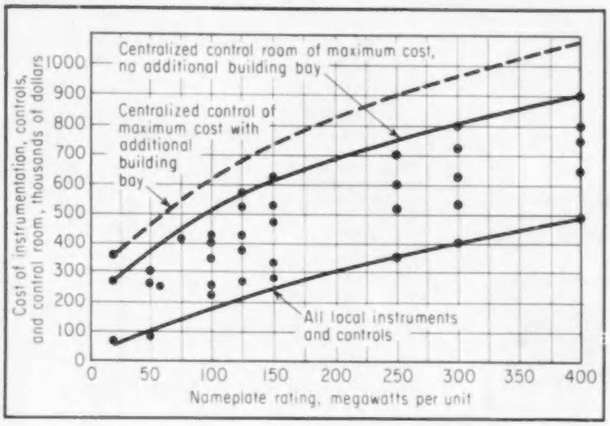
In reviewing the operation of the laboratory, Col. N. L. Krisberg, chief of ARL, supplied some interesting statistics. On its 325-man research staff, ARL can boast 40 PhD's and 70 men with master's degrees. Research in the laboratory is divided into an internal program (amounting to \$7½ million per year) and an external program running between \$6 and \$7 million. In the internal program, costs average out to about \$30,000 per man. On the average, half of this sum is spent for salaries and overhead, the other half for laboratory instrumentation.

—Lewis H. Young

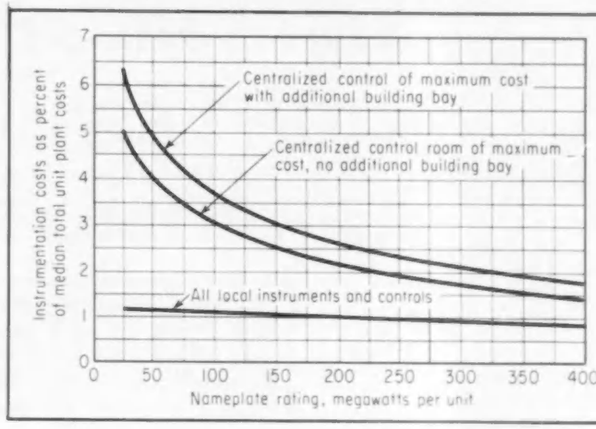
Missile model set up in hypersonic tunnel to reach speeds of Mach 18 (about 12,000 mph).



COSTS IN DOLLARS AND . . .



. . . AS PERCENT OF TOTAL PLANT COSTS



Figuring Costs For Power Plant Instrumentation

Costs were one of the key topics at ISA Power Division's first annual Power Conference. The sessions produced some interesting data relating instrumentation costs to total plant expenditures.

How much is the instrumentation in a new electric power plant likely to cost? That's a question that's probably asked every time a plant is planned. And usually there's no easy answer. But some useful guidelines were laid down in May by the men most intimately connected with the design of new plants—consulting engineers and constructors—at ISA Power Division's annual Power Conference meeting in New York.

One session started with a discussion of factors that help justify the use of instrumentation in a power plant. H. A. Johnson of Gibbs & Hill pointed out the extremes to be found in power plants, then listed the factors that make up the final decision on how well to instrument a power plant. His factors:

▶ improved efficiency expressed in terms of dollars saved. This pays for instruments and interest on investment—and as useful operating information to which it is difficult to attach an exact money value

▶ reduced maintenance, because instrumentation can prevent an extreme condition that might require frequent and expensive repair

▶ improved responsiveness of the plant. Although this is difficult to justify exactly in dollars, certainly improved responsiveness to any load change does result in savings.

Johnson also presented the results of analyzing instrumentation cost figures for a number of plants. The best correlation, he indicated, arises when the cost of instrumentation is expressed as a percentage of the total plant cost, not including the costs of ground, substructures, engineering, fees, etc. An analysis of medium-size generating plants varying from 44 to 100 megawatts showed the instrumentation and control costs varying from ¾ to 2 percent, with the average at 1.3 percent, of total plant cost. Another analysis, this time on the basis of instrumentation cost per kilowatt (adjusted to an *Engineering News Record* index of 750) showed a variation of $1.20 to $3.50 per kw, with an average of $1.75.

Thomas Mullen of Burns & Roe explained how the arrangement of instrumentation in the power plants affects overall cost. The greatest single decision on such arrangements, he said, is whether to use central control rooms or to use local instrumentation. A central control room brings into the cost picture such factors as control room space, enclosures, location, treatment (air conditioning, floor covering, sound-proofing, etc.), and graphic panels. An extreme situation in the use of central control rooms: where an extra bay must be added to the plant to house the room, and such costs must be rightly charged to instrumentation.

Mullen presented cost figures (see charts above) in graphical form for three situations: local control, centralized control room of maximum cost without additional building bay, and centralized control with bay.

In another paper, costs of electronic vs pneumatic instrumentation were compared. R. M. Maust of Gilbert Associates found little distinction between the two types of instruments cost-wise because specific information is obscured by such variables as labor rates, scheduling of work, and advantageous purchasing. From his study, he reported that instrumentation costs ranged from 0.84 to 1.21 percent of total plant cost.

Maust separated instrumentation costs into seven categories, reporting them as specific percentages of total

instrument and control expenditures:

Combustion control equipment—15 to 20 percent; steam temperature controls—2 to 5 percent; coal pulverizer controls—7 to 10 percent; pressure controls—4 to 6 percent; flow controls—9 to 11 percent; level controls—2 to 3 percent; remaining costs—cubicles, annunciators, etc.

Looking to the future, Bechtel's R. F. Myers predicted increased use of digital computers for power plant control, over and above those jobs (performance monitoring and heat rate and cost per kilowatt hour computations) now being done by analog computers. Another look at trends was presented by W. A. Summers, Ebasco Services, Inc., in the paper "Central Station Control, Today and Tomorrow".

—Harry R. Karp

Research in Components

In the armed services, which are almost totally systems oriented, it takes foresight, guts, or something else for R&D agencies to spend money on a "components" approach. So, Frankford Arsenal made news last month by awarding a contract to the Norden Ketay Corp. for advanced component development. The objective: to spur the design of a single line of standard components suitable both for routine applications as well as for the worse foreseeable operating conditions in military equipment.

In some quarters, the contract may be regarded as modest: it involves only $70,000 and is limited to a 1-year study stage on data transmitting devices (synchros). But anything but modest by present criteria is the aim to produce units that are:

- operable at 600 C over normal life spans
- compact, measuring only ½ in. in diameter (5 size synchros)
- accurate to plus or minus 1 min of arc; and
- standard for all applications.

Just what these mean becomes more evident when the present state of the art is reviewed. The smallest Army standard synchro is the 23 size (2.25-in. diam) rated for 100 C rise. It is possible today to obtain synchros measuring only ¾ in. in diameter, or operable at 200 to 300 C, or accurate to plus or minus 1 min of arc or better. However, such characteristics are pro-

vided only by derating the component in respect to some other parameters—and a derated component is a "special". The result is that a single military plane may be equipped with as many as several hundred synchros, each one a different, nonstandard item. Such a situation creates chaotic spare-parts stocking problems for the military.

• **The Army's view**—One enthusiastic supporter of the component approach is Anthony Bruno, who as chief of Frankford's Fire Control Laboratory, is close to the spare-parts headache. One of the basic difficulties, according to Bruno, is that many systems engineers ignore components until they've finished their designs. Then, the components people have to work under pressure to improvise something that will fit within the black boxes. Bruno wants standard units—but standards that offer the ultimate in performance (hence, the jump from 100 C to 600 C). His thinking is that systems designers, given such ideal components, will be as unhindered in their design efforts as they are when they demand "specials".

And Bruno proudly points out concrete evidence of the benefits of the components approach. Frankford, one of the military agencies that pay any heed at all to components, contributed heavily to the evolution of the 23 size synchro from the 5-in., "five-pounder" of World War II.

Bernard Levine (page 19), general manager of Norden-Ketay's Precision Components Div., admits that there is some real work ahead for his engineers before a 600 C unit can be developed. At that temperature, says Levine, steel glows red visibly in bright sunlight. And, there is a fourfold increase in the resistance of copper, so that a synchro tends to lose its inductive character.

• **The approach**—First, Levine plans to research components that are "recognizable as synchros". This will be largely a matter of substituting for existing materials. For example. Stellite, commonly used now for jet-engine blades, may appear in ball bearings. And, ceramics will certainly take over the job of insulation; organic materials, of course, are definitely out for 600 C service.

Then Levine plans to develop components that will "*not* be recognizable as synchros". His engineers have already worked out (on paper) a capacitive synchro that departs radically from established induction machine practice.

—John D. Cooney

Industrial Telemetry Gaining Ground

Visitors to a recent oil industry show were surprised at the emphasis on supervisory controls. But it's proof that telemetry is gaining widespread acceptance in process industries for data gathering and remote control applications.

Telemetry techniques are best known as a tool of aircraft and missile testers. Not so well known are the ways telemetering is being used in the process industries for transmitting both information and control signals. Last month, Shand & Jurs installed a brand new system at the Aurora Gasoline Co.'s Muskegon (Mich.) refinery. This new high speed Telepulse system demonstrates the unique problems of industrial telemetering.

Requirements for industrial telemetering are quite different than those for military systems. For one thing, industrial needs for accuracy dictate full digital techniques. Remote reading of liquid level in a gasoline storage tank, for example, requires an accuracy within $\frac{1}{8}$ in. over the full range of tank height, frequently 40 to 48 ft. And there's a trend to cut this down to $\frac{1}{16}$ or even $\frac{1}{32}$ in.

Another difference is in permissible transmission speed and message length. In missile testing, large volumes of information have to be moved quickly. But in petroleum applications, message transmission may take as long as 15 or 20 sec without any loss of operational efficiency. One reason for slower transmission rates: process industries want to use relatively low-grade communication facilities (for economy). Therefore, most systems are designed to operate over low-grade telegraph circuits. (Typical rentals: telegraph lines, approximately 75 cents per month per mile, compared to lowest quality telephone lines at $5.50 per month per mile.)

Under such transmission conditions it's easy to see why the full digital system is so popular.

The communication link carries simple equal-width pulses at 15 pulses per sec, with fidelity just sufficient to permit their being recognized as pulses at the end of the line. The receiving equipment doesn't have to distinguish between short and long pulses.

• **One new system**—Shand & Jurs' new Telepulse system—displayed for the first time at the joint Petroleum Industry Electrical Association-Petroleum Electric Supply Association annual meeting—differs from the earlier system in three main ways:

▶ speed—the gauging cycle has been reduced from 30 to 12 sec

▶ an automatic error-detecting circuit has been incorporated to reduce possibility of mistakes

▶ there are self-reporting alarms

The initial installation at Aurora will report remote readings of liquid level and temperature in petroleum storage tanks and remotely control pump motors and valves. Its ultimate capacity: 110 tanks, each measured for level and temperature. Over a single wire pair—telegraph quality—the same system opens and closes valves and starts and stops pump motors at an unattended marine terminal seven miles away.

The alarm system reports on an unsolicited basis any of 20 possible abnormal conditions. These include excessive tank level, high temperatures, high or low pressures, incorrect flow rates, fire, or any other unusual occurrence. An operator in the refinery's control room can both see the alarm signal on an annunciator and hear a horn sound it. He must acknowledge it by pressing a manual reset button.

• **Starts with digital address**—Here's how the telemetry system works at Aurora. The control station sends a digital address, unique to the function desired, over the single wire pair to one or more field selectors. The correct field selector answers, while all others ignore the address, then turns on the proper transmitter which starts sending.

First the transmitter sends its unique digital name, identifying both

WHAT'S NEW

the field selector and the transmitter. This is followed by one or two pulse groups representing liquid level, temperature, pressure, flow rate, or other process variable.

At the control station, the confirmation group from the transmitter is automatically compared with the selection group originally sent. If correspondence is established, the information following is received and displayed. If correspondence is not established, the entire message is rejected as an incorrect selection. This error can be caused by line faults (switching transients on leased lines, lightning-caused interruptions, etc.), or by equipment malfunction.

The control station also detects the presence of extra pulses or lost pulses automatically. Any error causes the entire message to be rejected, with both audible and visual warnings. The indications have to be acknowledged by resetting a pushbutton.

Control signals are dispatched in a similar manner. The equipment first reports the true condition of a distant device, then allows the operator to change it.

• **Limitations**—One limitation of the Telepulse system is that it uses selective supervisory control. That means only one of many parts can be remotely read or controlled at a time. Two or more points cannot be handled simultaneously and strictly continuous supervision is generally not possible, even on one point, because the single communication link is fully occupied by traffic from the point chosen and the nature of the message transmitted is sequential.

Telepulse's automatic self-reporting alarm transmitter can overcome these objections partially, by interrupting ordinary traffic to transmit a high-priority alarm signal whenever an abnormal condition triggers its action.

In addition, a recycler has been incorporated to interrogate a chosen point on a repetitive basis, once every 20 to 30 sec.

The function control unit is capable of true continuous monitoring of one point so long as point selection is unchanged and no alarm is received.

Costs of an industrial system are far below those of most airborne telemetry installations. Some typical industrial prices: digital level transmitter, \$250; pressure and temperature transmitters, from \$200 to \$500; control stations, \$700 to \$3,000, depending on complexity.

—Kemp Anderson
McGraw-Hill News

The dry and dustless direct-recording oscillograph that records without the use of powders, liquids, vapors, or other processing . . .

The new 36-Channel *Model 1012* VISICORDER OSCILLOGRAPH

is the only direct-recording oscillograph . . .

* that provides a consistently accurate grid line system (amplitude reference coordinates). By recording longitudinal reference lines *simultaneously* with galvanometer traces and timing lines, the reference is always accurate, even if the paper should shift slightly during recording, or is susceptible to subsequent dimensional changes.
* that can be loaded and unloaded *in a matter of seconds,* in daylight, without separate magazines.
* that permits running the record backward, as well as forward, for closer study and analysis.
* that gives you a choice of 5 time lines intervals (.001, 0.01, 0.10, 1.00, 10.0 second) recorded by means of a flash tube, with provision for external synchronization. External signals applied simultaneously to galvanometers and timing system are in exact time relationship on the record.
* that offers complete push-button control of record speeds, without changing gears, in 15 steps from 0.1 to 160 in./sec., with automatic recording intensity control.
* that provides "center galvanometer" performance in all galvanometer positions.
* that utilizes hermetically sealed plug-in galvanometers that do *not* require dummies in unfilled positions, and that are completely interchangeable between various models (700C, 906A-1) because optical arms (11.8") and, consequently, sensitivities are identical.
* that provides loading, operation and control from one surface.

. . . ***And these are just a few of its versatile features!*** The Model 1012 Visicorder is the most versatile instrument ever devised for converting dynamic data into immediately readable analog records. It has been specifically designed to make full utilization of the direct-recording Visicorder Principle that Honeywell pioneered and introduced with the Model 906 (see back cover). With the 1012, you can take records up to 200 feet in length with a wide selection of record speeds that provide maximum readability of the galvanometer traces even at the highest frequencies. You can record at frequencies from DC to 5000 cycles per second, at sensitivities identical to photographic-type oscillographs, and monitor the information as it goes on the record. The features of the Model 1012 give you conveniences never before possible in analog recording. Paper loading and unloading is quick and foolproof. A complete system of readily accessible controls, with indicator lamps, provides simple, positive control of recording. The 1012 records with or without longitudinal grid lines, as desired. Time lines may be varied through a choice of five ranges or not used at all; provisions for external timing are included. Galvanometer traces may overlap, with deflections as great as 8 inches peak-to-peak, and trace identification occurs on a 45° slope, interrupting galvanometer traces one at a time so that records are easy to read and analyze.

GENERAL FEATURES

FREQUENCIES & SENSITIVITIES
From DC to 5000 cycles per second without peaked amplifiers of any kind. Identical to photographic-type oscillographs.

RECORDING METHODS
Makes full use of the new Visicorder Principle. Records directly on paper which requires no powder magazines, liquids, vapors, or other processing. Daylight loading. Recording is accomplished in full view of the operator. Records are immediately visible and usable.

NUMBER OF CHANNELS
12, 24, or 36 active channels, as desired. Three magnet assemblies, each of which holds up to twelve ⅛" Series M Honeywell galvanometers, plus two reference traces.

RECORDING WIDTH
12" Visicorder paper (11⅜" for active recording; ⅜" margin for record numbering and event marking).

TRACE IDENTIFICATION
45° slope, interrupting galvanometer traces in sequence.

RECORDING SPEEDS
0.1 to 160 in./sec. Five speeds in each of 3 ranges (15 steps) via push-button control. No manual change of gears is required.

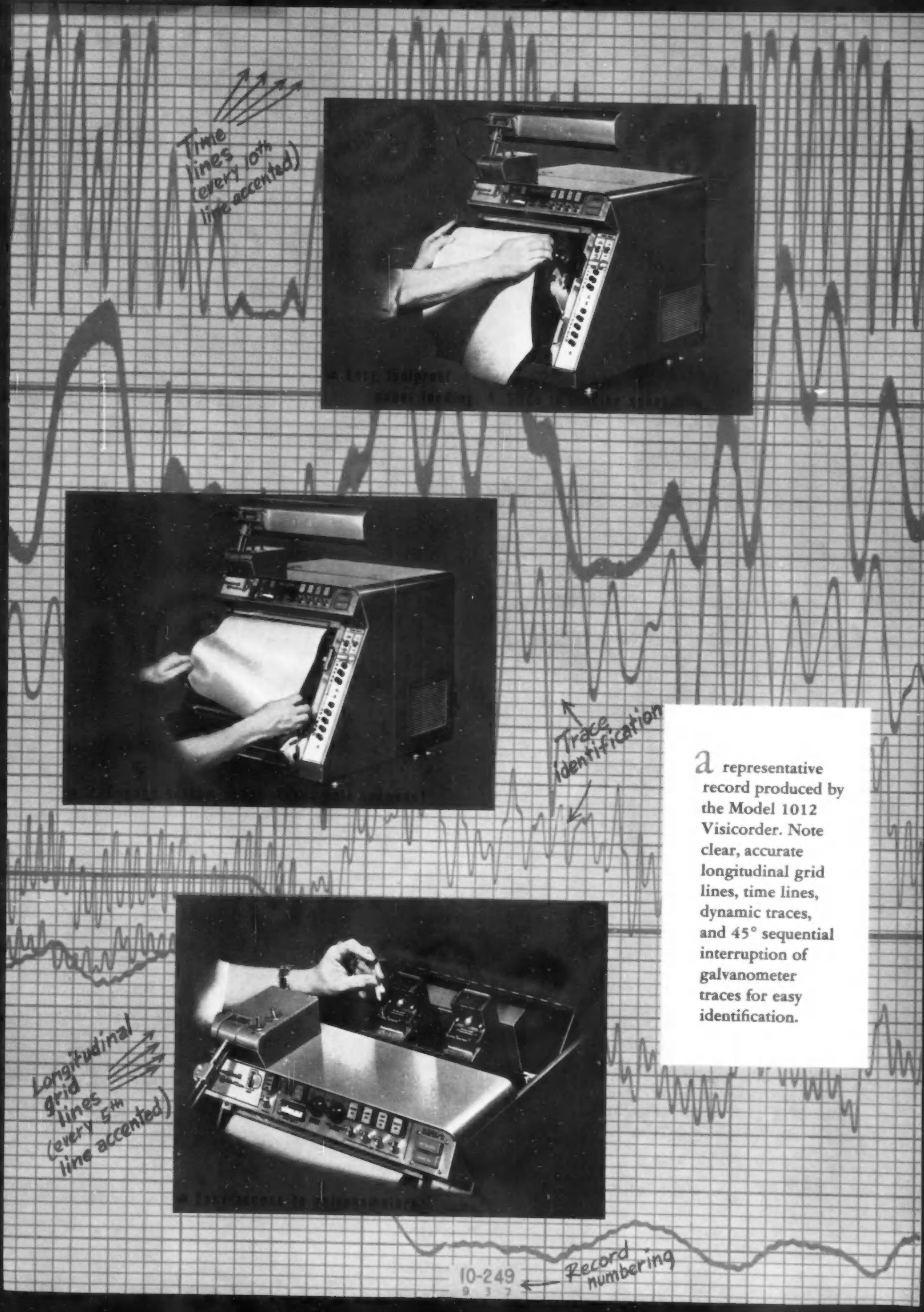
TIME LINES
Flash tube system. Choice of 5 intervals (.001, 0.01, 0.10, 1.00, 10.0 second) with each 10th line heavier. May be turned "off" or synchronized with external signals. With optical parallax being held to a minimum and negligible delay in initiating flash tube, timing lines and other data are recorded in exact time relationship.

RECORDING INTENSITY CONTROL
Proper aperture automatically established with record speed selection, or manually controlled as desired.

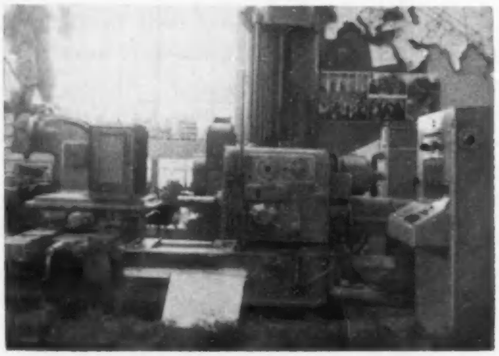
"NO RECORD" INDICATOR
Red indicator lamp and automatic shut-down of drive system indicates "No Record" if operator fails to turn on all necessary switches, if lamp fails, or if recording paper supply is exhausted. A separate lamp indicates when less than 25 feet of paper remains in supply.

PAPER LOADING
Simply done in a matter of seconds even by untrained personnel. All paper transport and take-up functions are integral. No separate magazines or other units required.

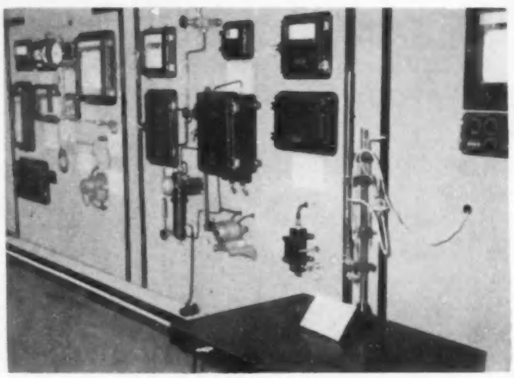
OTHER FEATURES
Automatic record length, adjustable 0-25' (forward or reverse). Unused paper indicator. Paper knife. Push-button jump speed control. Record numbering system with provision for external actuation. Integral fluorescent light Intensifier. Rack, table, or shock mounting. Provision for remote and/or multiplexed operation.



a representative record produced by the Model 1012 Visicorder. Note clear, accurate longitudinal grid lines, time lines, dynamic traces, and 45° sequential interruption of galvanometer traces for easy identification.



Punched - card - controlled horizontal boring mill with control cabinet at right.



Russian process instrumentation, primarily pneumatic, resembles U. S. product lines.

Previewing the Russians' Sales Pitch

Throughout Europe you hear rumors that the Russians are set for a big drive in world markets, particularly in the capital goods markets. European control makers have been keeping a wary eye open for any signs that the movement is under way. They fear what Soviet offerings at subsidized prices might do to their market position. Businessmen attending the Belgian World Fair got little comfort from what they saw in the Soviet's mammoth, temple-like building. The Russians were showing off the best they had; and it covered a wide portion of the control field.

There was no doubt that the Russians were proudest of their sputniks. Almost the first things you see when you enter are models of all the sputniks and their instrumentation (the Russians rushed in a full-sized replica of Sputnik III as soon as they were sure it was in orbit). But to worried businessmen, the display of industrial control applications was even more impressive. It included:

▶ a magnetic tape system to control a vertical milling machine for continuous contouring

▶ punched card control for a horizontal boring machine

▶ process controllers and recorders that closely resembled equipment built by U. S. companies

The magnetic tape system provides linear interpolation on a vertical milling machine. Accuracy claimed: 0.2 mm in all three directions; longitudinal travel, 1 meter. One of the most startling features is complete transistorization, which shrinks the reader, interpolator and control system so that all three fit into a panel unit only 10 by 19 in.

The point-to-point system on the horizontal boring machine uses an unusual cylindrical card reader which

WHAT'S NEW

. . . in the Czech building, a photoelectric curve follower . . .

reads the 44-column card carrying the five-digit command signals for each of the three axes. The cards are bent around a cylinder, then scanned by a series of rotating wipers. The sequential information is stored in relays; positional information is determined from photocell pickoffs operating on graduated scales which are mounted on the bed and column of the machine.

Other numerical control on display: punched tape controls for a lathe and a milling machine. Both of these systems are transistorized. Positioning accuracy was claimed to be 0.02 mm. Russians manning the booths claimed that 10 machines with these controls are already in use on production lines in the U.S.S.R.

• **Process control speculation**—The display of controllers and recorders for process industries started a lot of speculation. The gist of it: with Russian activity already stepped up on a world-wide basis in the construction of complete plants (typical example: steel mills in India), the next step will be a commercial drive on the instruments themselves at subsidized prices.

The process instrumentation displayed resembled U.S. lines quite closely. They were mainly pneumatic and solidly constructed. Performance claimed for them was equivalent to their American counterparts.

Down the street from the Russian exhibit, Czechoslovakia, a Soviet satellite, also showed off some interesting control equipment. One application was a photoelectric curve follower positioning the table of a spark erosion machine. Because a drawing of the curve is fitted into a slide which mounts underneath the worktable, the pattern and worktable form an integral unit. A simple fixed light source and a photocell pickup operate a servo positioning system. Positioning accuracy is said to be 0.1 mm.

Another example of Czech ingenuity was the use of a radioisotope as a random pulse generator for statistical machines. The machine on display determined the probability distribution of rejects on large production runs from varying small batch inspection samples.

Elsewhere at the fair, control exhibits were hard to find. That made the Russian emphasis in the field even more foreboding.

—Derek Barlow

THOMAS A.

EDISON

subminiaturized servo program computer

Analog computers, advanced chemical and physics test equipment spell out the dimensions of the Edison Research Laboratory—one of the finest facilities of its type anywhere.

Edison's new servo program computer for an advanced—and classified—missile system sets new standards in lightness and compactness. Built entirely with Edison-manufactured components, this new unit weighs only 14 ounces, occupies only 14 cubic inches.

Within this size and weight Edison has created a complete servo computer package—containing transistorized and magnetic amplifier circuitry, servo-motor, precision gear train, two resolvers in a complete servo loop. The whole unit is hermetically sealed and highly resistant to corrosion and vibration.

Offering an optimum in response and sensitivity, this system shows the way to a wide variety of applications in missile control duties. It exemplifies the Edison capability in missile system design and manufacturing.

Because the Edison organization includes development and production facilities for servos, servo systems, magnetic amplifiers, computers, transducers, precision gear trains and miniature relays, Edison can become the *single source* for major electronic system assignments . . . can speed up prototype development faster than any other company. The Edison team concept in engineering, and unexcelled research laboratories for its scientists—are the other basic ingredients for success in advanced electronics projects.

For complete information on Edison capabilities, write to:

Thomas A. Edison Industries

INSTRUMENT DIVISION

38 LAKESIDE AVENUE, WEST ORANGE, N. J.

EDISON FACTORY OFFICES ARE LOCATED IN EVANSTON, ILL.; DALLAS, TEX.; DAYTON, OHIO; SHERMAN OAKS, CALIF.; AND TAMPA, FLA.

AROUND THE BUSINESS LOOP

Foxboro Opens Its Books

Lofty New England company shows its financial strength as its stock goes on the open market for the first time.

The Foxboro Co. is a prim-mouthed, family-type corporation of the old school that owes its phenomenal success to a policy of always keeping ahead of the other fellow in research and development. Last year, for example, it grossed more than $4 million in sales and netted more than $1 million in profits, bringing the first up to $16,218,865 and the second to $3,947,209.

But success, Foxboro has found, cannot be kept in the family, for it demands that working capital be increased, and that can best be done by going to the public.

For this reason the company recently wrote "finis" to a 44-year-old reign by the members of its founding family, and announced plans to put 120,000 shares of common stock on the open market.

• **Elbow room**—The $1 par value stock will be offered at $25 per share, according to a Foxboro prospectus dated April 7, 1958. This will gross $3 million, of which $168,000 will be paid to underwriters in discounts and commissions. Foxboro thus will realize $2,832,000, which will go toward the "full utilization" of an additional 165,000 sq ft of working space, now under construction.

Paving the way for the offer was a stock split March 8, which produced 16 shares for every one outstanding. Nine underwriters, five in New York City, three in Boston, and one in Providence, R. I., will float the offer for which, says the Foxboro prospectus, there is no quoted market.

An important result of the offer is to open the company's books to the public for the first time since Foxboro was incorporated in 1914 by Edgar H. and Bennet B. Bristol. Today other Bristols, Benjamin H. and Rexford A., are the principal stockholders. They and their fellow officers and directors owned, as of March 11, 605,568 shares of Foxboro common stock, or 60.5 percent of the shares outstanding. This stock has paid dividends every year for the past 42 years.

Social Calendar Sags

Control companies continue to marry and break engagements at a feverish pace, despite a general slowdown of business.

One activity on which the business recession seems to be having little effect is company expansion, either actual or contemplated. That is not to say that more companies have branched out or consolidated than ever before; for the fact of the matter is that several talked-up mergers have been called off in this period. But there is an unusual amount of planning and discussing going on these days, and for every company that has called off a merger or a purchase, another has gone through with one.

Take, for example, the hopeful story in the December issue (page 50), which made a bare fact out of Litton Industries' intended purchase of Aircraft Radio of Boonton, N. J. A strong group of Aircraft Radio stockholders who saw Litton getting a much better break in the negotiations than their own company quickly threw in a wrench, and there was no more talk at Aircraft Radio of going over to Litton. There was, in the words of one Aircraft Radio man, a great deal of mutual admiration, but no deal.

Litton promptly went after new game, and very soon afterward was able to announce the purchase of Roger White Electron Devices, Inc., of Haskell, N. J., manufacturer of backward wave oscillators, traveling wave tubes, and gas discharge tubes for microwave applications.

• **Another in the dust**—At approximately the same time, Consolidated Electrodynamics Corp. and Cenco Instruments Co. called off their wedding, too. Main reason for terminating the talks was said to be an incompatibility in personnel policy; i.e., Cenco felt a loyalty to certain workers who would have had to go, under the terms of the merger.

But a few big positives have appeared, to balance all these negatives.

For, one Cutler-Hammer, Inc., has acquired Airborne Instruments Laboratories, Inc., of Long Island, N. Y.

(see page 44); for another, Bausch & Lomb Optical Co. has definitely consolidated with Applied Research Laboratories; for still another, Sundstrand Machine Tool Co. has acquired all the product lines of Arter Grinding Machine Co. (CtE, Jan., p. 80); for still one more, Midwestern Instruments, Inc., has wrapped chubby, young fingers around Modern Art Finishing Co. of Chicago; and finally, Norden-Ketay has gone over to Solar Aircraft (CtE, March, p. 48).

Fluid Controls Institute Acts on Members, Dues, Standards

At a lively three-day annual meeting at Lake Placid, N. Y., in May, the Fluid Controls Institute made important changes in its membership and dues structures, elected new officers, and heard a control valves subcommittee on a long-awaited recommendation for standard test procedures and standard ratings.

The new membership structure, formalized by a change in the institute's bylaws, establishes company memberships in place of individual memberships. Since there are 91 companies in the group and 155 individuals, the result is a streamlined roster. Not everyone, it seemed, liked the idea, and it remains to be seen what the dissatisfied companies and individuals plan to do about it. The new dues structure is based on the number of employees in the member companies whose work is within the scope of the institute.

The new officers are Dean E. Madden, A. W. Cash Valve Mfg. Corp., president; J. R. Lawler Jr., Lawler Automatic Controls, Inc., first vice-president; Fred Weldon, General Controls Co., second vice-president; R. F. McCormick, Automatic Switch Co., secretary; and Paul K. Rogers Jr., Skinner Electric Valve Div. of Skinner Chuck Co., treasurer. John S. Leslie, Leslie Co., retiring president, becomes chairman of the board.

Seventy percent of all control valves yield to a standard test. That is why the work of the institute's subcommittee on standard test procedures and ratings for control valves is so important. The report by this subcommittee, dealing with such specifics as location of pressure taps, choice of pressure levels, testing fluid, and type of meter run before and after the valve, and the determination of accuracies to be expected from valve tests, was approved in full by the parent com-

mittee. Approval by all members of the Control Valves Section, viewed as simply a formality, is next. Ratification will probably take place at the institute's September meeting.

Cutler-Hammer Acquires Airborne Instruments Lab

"We came to the realization several years ago that if we were to maintain our market position and to expand in the electrical control field, we had to branch out strongly into electronics," said President Philip Ryan recently, in announcing that his company, Cutler-Hammer, Inc., had acquired Airborne Instruments Laboratory, Inc. Terms include a share-for-share stock exchange, additions to the Cutler-Hammer board of AIL's President Hector R. Skifter and director Randolph B. Marston, and a C-H vice-presidency for Skifter.

The 1,500 employees of AIL, which started in a Columbia University Laboratory during World War II, make up Cutler-Hammer's new Electronics Div. A new plant will be built at Melville, N. Y., to supplement facilities at Garden City and West Hempstead. Said Skifter: "We will be in a position to enter into technical areas which prior to this pooling of efforts and interests could not be made because of AIL's lack of manpower and facilities."

Cutler-Hammer's 6,000 employees produce electrical control equipment, systems for continuous processes, aircraft and missile power relays, and low-voltage distribution devices. The AIL addition gives it not only an electronics division, but an R&D arm as well.

EIA Team to Develop Panel, Enclosure Standards

Electronic Industries Association is putting a 30-man team to work on standards for racks, panels, and enclosures. Objectives are a clearer picture of existing standards and possible development of some new ones. Under Herbert C. Golz, general manager of Elgin Metalformers Corp., which created the modular enclosure system, the team will look into:

- the feasibility of departing from the present 19-in. standard panel width
- the advisability of setting standards for screws, fasteners, weight-to-

strength ratio of fasteners, and tolerances
- the possibility of clarifying nomenclature for racks and enclosures
- standards for enclosure heights, widths, depths, shapes, and required load factors
- standards of materials and finishes, classification of finishes

Golz is chairman of EIA's engineering committee G-9. The standards team will divide into four subcommittees under this group.

Civil Service Holding Tests for Electronic Technicians

As of last May, and until further notice, says the U. S. Civil Service Commission, it will be holding examinations for electronic technicians to fill jobs in Federal agencies. These jobs pay between $3,175 and $7,570. Applicants must demonstrate a competence in R&D and an ability to install and maintain computers, detectors, testing and communications equipment, and other electronic equipment. Your local post office has all the information; so does the U. S. Civil Service Commission, Washington 25, D. C.

Schlumberger NMR Analyzer Available on a Rental Basis

Schlumberger Well Surveying Corp. has put a "for rent" sign on its NMR (nuclear magnetic resonance) high-speed moisture analyzer, the plus-$13,000 instrument that makes quantitative measurements of moisture content in from 30 sec to 4 min. "Under the terms of this plan," said Sales Manager A. Russell Aikman, "many companies doing moisture analysis in volume can rent the Model 104 at $495 per month for a trial period of three months, and this rental will all be credited against a purchase price of $13,400." Schlumberger will provide all maintenance and service during the period of the lease.

First Prospectus Reveals Structure of a Control Fund

Today Theodore von Karman is chairman of the Advisory Group for Aeronautical Research & Development for NATO, and Andrew G. Haley is a partner in the Washington D. C. law firm of Haley, Woolenberg,

ALL-ELECTRONIC DIGITAL VOLTMETER...ONLY $960

MEASURE
MILLIVOLT TO
KILOVOLT WITH
0.1% ACCURACY

no moving parts
digital in-line readout
70 millisecond conversion time
adjustable display time
direct voltage conversion

Here at last is a portable all-electronic digital voltmeter that measures DC voltages from .001 to 1000 volts with 0.1% accuracy. In less than 1/10 of a second the measured voltage is presented in clear numerical form on a digital in-line readout that even unskilled personnel can read quickly and accurately, with little possibility of error. *Direct* voltage measurement by successive approximation provides accuracy and sensitivity previously obtainable only in the delicate, complex and expensive instruments. Extremely stable operation – continuous calibration against an internal reference.

The low price of the Model 801 allows you to put one on every bench. Its accuracy and reliability are assured by KIN TEL's years of design and manufacturing experience . . . experience gained in the manufacture of more than 10,000 precision electronic instruments.

BRIEF SPECIFICATIONS (model 801)

Ranges....0.000 to 1.599; 00.00 to 15.99; 000.0 to 159.9; 0000. to 1000 volts (manual ranging and polarity)
Accuracy....0.1% of full scale
Readout....4 digits plus decimal point
Input Impedance....20,000 ohms per volt*

*The Model 802 provides 10 megohms input impedance. Price $1190. In other special models the binary coded decimal and decimal outputs are externally available to permit use as an analog to digital converter.

Conversion Rate....10 per second
Conversion Time....approximately 70 milliseconds
Display Time......Adjustable from approximately .1 second to infinity (plus push-button *read once* control)
Dimensions....11" high x 7½" wide x 20" deep
Power Requirements...105 to 125 volts, 60 cycle AC, 180 watts

5725 Kearny Villa Road, San Diego 11, California. Phone BRowning 7-6700

KIN TEL
A Division of Cohu Electronics Inc.

Representatives in all major cities. Write today for demonstration or literature.

& Kenehan. Though separated by more than half a continent (von Karman is in Pasadena), their interests dovetail much as they did when the two men founded Aerojet Engineering Corp. and von Karman became chairman and Haley president. Evidence is the fact that just lately they joined hands again, as chairman and president of a new mutual fund known as Missiles-Jets & Automation Fund, Inc.

In a preliminary prospectus, von Karman, Haley, and other officers, through underwriter Ira Haupt & Co., New York City, declare that the fund will offer 500,000 shares of securities of companies "which have growth potential in the fields of missiles-jets and automation". Common stock will make up the bulk of the portfolio.

The fund was to have purchased its first securities 30 days after the date of the prospectus (May 8, 1958). As of June 1, then, its portfolio still empty, its biggest claim to interest was that it could provide a glimpse into the newly-minted structure of a mutual fund dedicated expressly to control engineering.

• **Nucleus**—Besides von Karman and Haley, there are eight other directors of the fund, plus a vice-president and a secretary-treasurer. In addition to the supervision it will receive from these men will be that issued by a technical advisory board made up of eight college educators from all over the U. S. Business affairs will be handled by Missiles-Jets & Automation Management Co., Washington, D. C., of which Haley is president.

Shares will be offered through the Haupt company on a continuous basis at a date to be determined.

New Divisions and Groups

A Digital Devices Dept., whose parent, **Gulton Industries, Inc.**, has mapped out three stages of growth: designing and manufacturing transistorized instrumentation; building digital systems for special applications; and developing computer instrumentation. Harry B. Barling, formerly of Sandia Corp. and Bell Telephone Laboratories, hires on as manager of the new department, which has been assigned to Gulton's CC Electronics Corp. at Albuquerque, N. M.

A New Product Development Div. to concentrate on industrial electronics, for **General Instrument Corp.** Manager is Lawrence R. Hill, most recently chief of Westinghouse's Ma-

For digital-computer input/output

Ampex offers 45,000 to 90,000-character transfer rates

For high-speed computer input and output, magnetic tape is the answer – and Ampex offers the fastest equipment of all. Just for sport, this Ampex FR-300 could "read" or "write" the digitized equivalent of an average 500-page book in just 13 seconds. Or it could go through the equal of that whole man-sized stack in less than five minutes.

But the real point is that these fast input/output rates are needed. They set the pace that determines computer productivity. Incorporating Ampex Digital Tape Systems for these functions will speed up your whole digital-computer package. Spectacular? Impressive? Yes, but speed is also a tangible and conclusive advantage in the sale of *your* equipment.

TO GIVE YOU THIS GREATER SPEED

The Ampex FR-300 Tape Handler operates at 150 inches per second, a two-to-one advantage over previous standards. It packs 300 bits per inch onto the tape. And FR-300 handlers are available for one-inch tape affording the very practical possibility of putting two 6-bit alpha-numeric characters side by side across the greater width. To get high performance, Ampex has taken a systems approach, designing the tape handler, magnetic heads, amplifiers and the magnetic tape as an integrated whole.

Ampex transfer rates in characters per second	
90,000	150 in/sec. tape speed; 300 bits/inch; two 6-bit characters side by side on 1-inch tape.
60,000	Same as above except 200 bits/inch.
45,000	150 in/sec. tape speed; 300 bits/inch; one 6-bit character across half-inch tape.
30,000	Same as above except 200 bits/inch.
Lower transfer rates are available from a wide range of slower tape speeds available on Ampex tape handlers.	

DEPENDABILITY, TOO, PROVED IN 50-MILLION STARTS AND STOPS

Though the transfer rates accomplished by the Ampex Digital System are faster than any available before, our engineers have evolved mechanical and electrical design details that make this an easy pace. During development, the most critical of these parts were subjected to as many as 50-million start-stop cycles. This would be a normal year of heavy-duty operation. By drastically reducing downtime expectancy from tape-handler problems, Ampex has contributed still another factor toward increased computer work per day.

A TECHNICAL HEADSTART YOU CAN PUT ON YOUR SIDE

This is magnetic-tape equipment – our specialty. In buying from Ampex, you are "hiring" the very best existing experience and manpower in this field. Behind the Ampex 90,000-bit transfer rate, there are engineering skills and manufacturing techniques accumulated in ten years of specialized effort. This equipment is in production – ready today to give you a competitive advantage – so why divert your own best brains from other critical aspects of computer design?

For full description and specifications, write Dept. HH-14

AMPEX INSTRUMENTATION DIVISION • 860 CHARTER STREET • REDWOOD CITY, CALIFORNIA

Phone your Ampex data specialist for personal attention to your recording needs. Offices serve U. S. A. and Canada. Engineering representatives cover the free world.

terials & New Products Engineering Section.

A Military Projects Div. for **Cohu Electronics, Inc.,** under Peter H. Kafitz, formerly with the Naval Ordnance Laboratory and the University of California's Radiation Laboratory. Major contracts with the Naval Bureau of Ships and with Convair–Astronautics are already in the works. A sample: development of versatile power-supply systems for the Bureau of Ships to reduce the high number now in shipboard installations.

A Special Products Div. for **Servomechanisms, Inc.,** the result of a consolidation of the company's Magnetics and Vacuum Film Products divisions on the West Coast. Marketing and administration procedures are the principal items involved in the consolidation; manufacturing arrangements are virtually unaffected. William T. Smither, who headed Magnetics, will manage the new division, and David W. Moore, who was in charge of Vacuum Tube Products, will direct applied research at the company's Research Laboratory.

A Systems Engineering Group in the Instrument Div. of **Beckman & Whitley's** Engineering Dept. Edward F. Kingman, with B&W since 1952, will see that the new group adheres to its *raison d'etat:* integration of sensor instruments into large-scale meteorological systems.

An Electronics Mfg. Div. in Mineola, N. Y., for **Acoustica Associates, Inc.,** to build simulators, computers, amplifiers, power supplies, and telemetering equipment, as well as Acoustica's own ultrasonic equipment. Director of manufacturing for the division is Samuel Markel, formerly president of Advance Electronics, Inc., Westbury, N. Y., which he helped found.

An Airborne Instrument Mfg. Dept. to produce flight control components and systems for the parent **Collins Radio Co.** The new department is autonomous with respect to all phases of production.

Four new divisions (Electronic Counters, Oscilloscope, Microwave & Signal Generator, and Audio & Video Equipment), two new sections (Advanced Development and Industrial Design), and a new Standards Laboratory, all for **Hewlett-Packard Co.** The four divisions are a result of a reshaping of the R&D Dept. Managing them are Alan S. Bagley, Norman B. Schrock, W. Bruce Wholey, and John M. Cage. B. P. Hand heads the new standards lab.

TUNG-SOL POWER TRANSISTORS IMPROVED THREE WAYS BY:

NEW Cold-Weld SEAL

Tung-Sol's new true cold-weld seal represents a major advance in transistor technology. An exclusive Tung-Sol development, cold-weld sealing increases TO-3 outline package efficiency and brings designers a threefold bonus in over-all transistor performance.

Improved thermal qualities. The cold-weld process produces a hermetic, copper-to-copper seal and makes possible a 100% copper transistor with thermal properties superior to previous high power types.

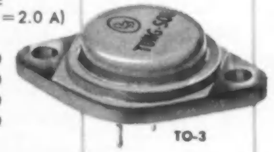
Improved reliability. Cold-weld encapsulation eliminates heat damage, "splash", and heat-caused moisture that can impair transistor performance.

Longer efficient life. Even through temperature fluctuations that cause "breathing", the cold-weld seal stays vacuum-tight, moisture-proof—result of actual integration of the copper molecules during sealing.

Tung-Sol power switches with the new cold-weld seal withstand the most rigid combination of tests given any transistor—the 100 psi "bomb" immersion test and the critically sensitive Mass Spectrometer leak test. Further, they meet all military environmental requirements. For full data on the improved Tung-Sol types . . . to fill any transistor need, contact: Semiconductor Division, Tung-Sol Electric Inc., Newark 4, New Jersey.

THESE TUNG-SOL HIGH POWER (TO-3 OUTLINE) TRANSISTORS FEATURE THE NEW, COLD-WELD SEAL

Type	BV_{CES} ($V_{BE}=+1.0v$) Volts (Min)	BV_{CEO} ($I_B=0$) Volts (Min)	h_{FE} ($I_C=1.0$ A)	h_{FE} ($I_C=2.0$ A)
2N378	—40	—20	50	30
2N379	—80	—40	50	30
2N380	—60	—30	70	50
2N459	—105	—60	50	30



TO-3

IMPROVED SPECIFICATIONS OF TUNG-SOL COLD-WELDED HIGH POWER TRANSISTORS.

Collector Dissipation @ 25°C*...50 Watts
Collector Dissipation @ 55°C*...25 Watts
Thermal Resistance.............1.2° C/Watt Max.
I_{CBO} @ $V_{CB}=-25v$ T=25°C...0.5 Ma Max.
I_{CBO} @ $V_{CB}=-25v$ T=85°C...7.5 Ma Max.
Storage Temperature...........—55 to +100°C

Mounting base temperature

TUNG-SOL®

IMPORTANT MOVES BY KEY PEOPLE

W. L. Maxson Man Gets Coveted Cambridge Degree

A consulting scientist at The W. L. Maxson Corp. has been awarded the coveted and rarely issued ScD degree of Cambridge University, Cambridge, England. The consultant, Raymond M. Wilmotte, was cited for his original contributions to electronic engineering. At present Wilmotte is working on guidance, fire-control, countermeasures, and radar map-matching problems.

Three Key Sales Jobs Filled, Two by Top Engineers

Three top sales jobs in control have been filled by men who have come up through the ranks, two by way of the engineering route and the other by way of the administrative one.

The men are William H. Doherty, formerly assistant to the president of Bell Telephone Laboratories, who has been named manager of government sales for the Radio Div. of Western Electric Co., Inc.; Russell Quackenbush, who leaves Instrument Development & Mfg. Co., where he has been chief engineer, for Owen Laboratories, Inc., where he will be sales manager; and William G. Zaenglein, most recently president of Underwood Corp., who has been named executive vice-president and general sales manager of Clary Corp.

With Bell Labs since his graduation in 1929, Doherty is responsible for the invention of a high-efficiency power amplifier for broadcasting and for the successful efforts of a wartime radar-development team. He was named director of electronic and television research by Bell Labs in 1949 and director of research in electrical communications in 1951. His more recent positions in the organization have been administrative. He is a fellow of the IRE.

Before signing on with IDM, Quackenbush was with Consolidated Electrodynamics Corp. as project chief for systems, and with the Navy as an electronics engineer in test range instrumentation and missile guidance radar. His appointment at Owen coincides with that of Monte L. Marks, the new chief engineer, who was formerly chief development engi-

neer for CEC. Marks succeeds Warren H. Paap, who has also gone into selling.

Zaenglein got his professional start with Monroe Calculating Machine Co., which named him sales manager in 1928 and president in 1937. He left Monroe for Underwood in 1956, taking the reins of the latter company in 1957.

Inventor Henri Busignies Heads New IT&T Division

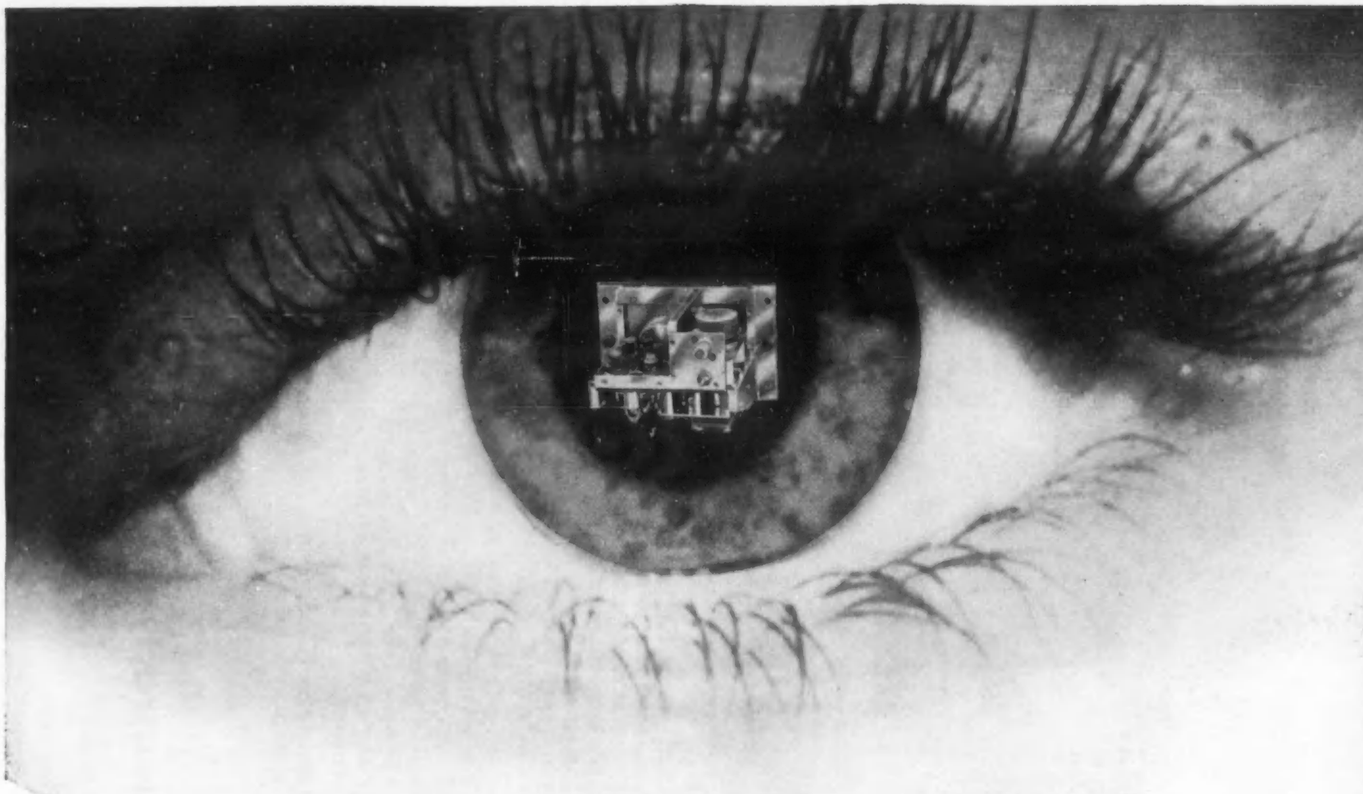
The president of International Telephone & Telegraph's IT&T Laboratories, a new division, is said to be inventor of the world's first automatic direction finder and holder of more than 100 patents in aerial navigation, radar, and communication. He is Henri Busignies, who joined IT&T in 1928 at its Paris laboratories and helped found Federal Telecommunication Laboratories in 1941. Since 1956 Busignies has been president of FTL.

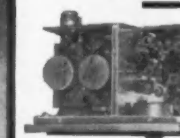
His new division will direct all the work of IT&T's seven American laboratories. Explained IT&T President Edmond H. Leavey: "More effective utilization of and opportunities for the talents of our scientists and engineers, many of whom are working on vital communications, missile, and countermeasure projects in the defense program, will be one of many advantages of this new structure. Our research budget has been expanding steadily in step with our growth in the electronics and communications industries, and this change is designed to meet the needs of that expansion."

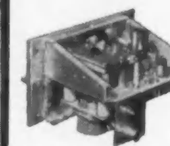
Other Important Moves

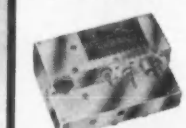
As the new chief engineer in the Applied Science Dept., **Robert J. Bibbero** directs Bulova R&D Laboratories' work in weapons and industrial systems analysis, systems management, and applied science and mathematics consulting. Previously, he was acting head of the Automation Dept. Among his former affiliations are Hillyer Instrument Co., Republic Aviation, Bell Aircraft, and Linde Air Products Co.

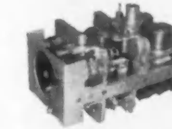
Sidney J. Stein, named director of engineering and research by International Resistance Co., joined IRC in 1949 and advanced through the positions of senior research chemist and assistant director and director of research. He is a fellow of the American Institute of Chemists. Concurrently, **George C. Williams** becomes chief engineer at Philadelphia, **George T.**











WHAT'S NEW

Brent chief engineer of IRC's subsidiary Circuit Instruments, Inc., of St. Petersburg, Fla., and **David E. McElroy** manager of plastics research at Philadelphia. Williams joined the company in 1952, Brent in 1955, and McElroy in 1953.

While stockholders weighed a proposal to merge Marchant Calculators, Inc., and Smith-Corona—they were to have voted June 26 (CtE, June, p. 46) —Marchant continued a business-as-usual policy, brought in **Alan F. Kelsey** from Magna Power Tool Corp. of Berkeley, Calif., as director of manufacturing. Kelsey held the same post at Magna. Earlier, he had been with Hiller Engineering Corp. and Boeing Airplane Co.

Joseph M. Denney, who has been in charge of solid-state physics at Aeronutronic Systems, Inc., since 1956, has joined the Nuclear Electronics Dept. of Hughes Aircraft Co. Before 1956, he was a research associate with GE and a research assistant at Caltech. The new director of engineering in Hughes' Ground Systems Group is **Nicholas A. Begovich**, a specialist in electronic scanning radar and landing and approach systems, who joined the company in 1948.

Other new Hughes appointments: **William T. Clary Jr.** to head of the Systems Analysis Dept., **John W. Bozeman** to director of the Data Processing Laboratory, **Robert Polkinghorn** to director of the Radar Laboratory, and **Samuel Langberg** to head of the Engineering Services Dept. Clary and Bozeman joined Hughes in 1955, Polkinghorn in 1948, and Langberg in 1949.

W. E. Elder goes from Bendix Aviation Corp., where he has been chief hydraulics engineer, to Dalmo Victor Co. as manager of hydraulics engineering.

Irving Glassman and **Robert B. Dickson**, both responsible for outstanding developments in airborne electronic systems, have joined Auerbach Electronics Corp., Glassman as senior project manager and Dickson as senior member of the technical staff. Glassman comes from Franklin Institute's Research Dept. Dickson was formerly chief systems engineer for the Atlas missile.

Obituaries

Walter Ferris, 90, co-founder (1921) of The Oilgear Co.; in Milwaukee.

Frank Berry Sanborn, 93, founder (1917) and chairman of Sanborn Co., Waltham, Mass.; in Cambridge.

simple

portable

inexpensive

FLIGHT SIMULATION TABLE

Micro Gee Model 10C

is a single-degree-of-freedom roll table designed for small amplitude perturbation studies about null.

Used by many leading aircraft and missile manufacturers for testing gyros, accelerometers and automatic stabilization systems, either statically or dynamically.

This important tool has a threshold of less than 5 microradians — approximately one second of arc — and is ideal for frequency response and dynamic threshold measurements. It takes loads up to 5 pounds on a 6″x6″ base. Extremely smooth operation is provided by specially-designed, electro-dynamically driven, pendulum mechanism that eliminates the problems created by friction, backlash and use of conventional bearings.

Model 10C is easily used in a closed loop with an analog computer for simulated flight testing of automatic flight control equipment on the ground.

Get complete data on this simple, portable, inexpensive, single-degree-of-freedom roll table that is designed for small perturbation stability studies. Write or phone . . .

New Model 12A Micro Gee Simulation Table takes loads up to 50 pounds on a 12″x12″ base. See it at Wescon, Booth 1709

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THE NEW LIGHTWEIGHT A-MP "240" PATCHCORD PROGRAMMING SYSTEM

. . . means lightning fast in-flight reprogramming of airborne electrical/electronic circuitry . . . obsoletes fixed circuit connectors and other systems requiring hours or days to rewire . . . and offers these unusual features:

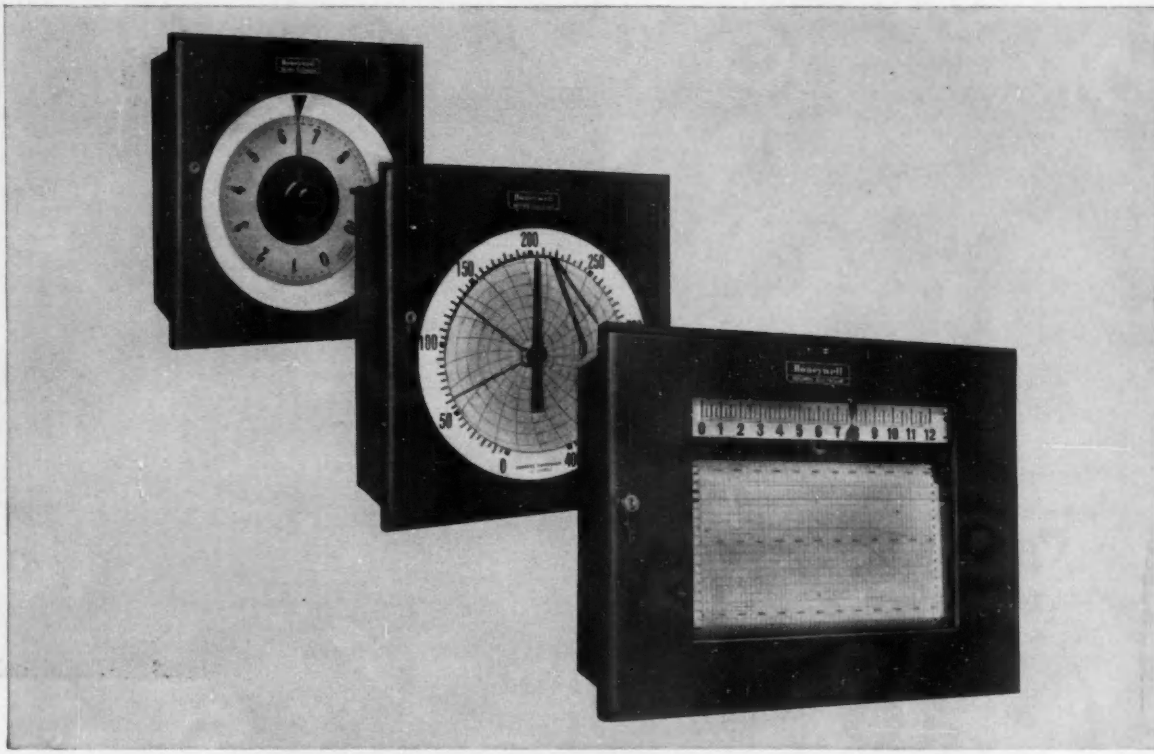
- removable patchboards to permit complete reprogramming in seconds
- 3¼ pounds to minimize weight . . . miniaturized to conserve space
- rugged shock and vibration-resistant construction with high strength aluminum alloy
- shock-resistant seating of patchcord plugs in removable board
- AMP's patented wiping action that pre-cleans contacts for top electrical performance
- 240 contacts for greatest versatility in circuit combinations or program arrangements

For more information on this new airborne wiring technique, AMP's Patchcord System Catalog is available on request.

AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

A-MP products and engineering assistance are available through wholly-owned subsidiaries in: Canada • England • France • Holland • Japan



the *ElectroniK* recorder or indicator is a thousand instruments in one

An *ElectroniK* instrument adapts easily to your changing needs, never becomes obsolete. Its remarkable versatility is made possible by the many measuring circuits . . . many types of records or indications . . . many pen or print wheel speeds . . . and the wide variety of functions that can be incorporated in the instrument.

You can convert most *ElectroniK* instruments to practically any scale, simply by soldering appropriate kit-supplied range resistors into the measuring circuits. And you have a choice of more than 575 *standard* charts and scales in strip chart instruments (similar large choice in indicators and circular chart models). You can change chart speeds from one half to four times the basic speed, with a simple gear change.

Use *ElectroniK* instruments to measure temperature, pressure, flow, pH, chemical concentration, voltage, speed—*any* variable that's translatable into a d-c signal.

Unitized construction lets you transfer complete control units from one *ElectroniK* instrument to another. Cases are designed for both surface and flush panelboard mounting. With auxiliary switches, the instrument works in conjunction with audible or visual alarms and safety cutouts.

Your nearby Honeywell field engineer can help you gain the advantages of *ElectroniK* versatility in specific applications. Call him today. He's as near as your phone.

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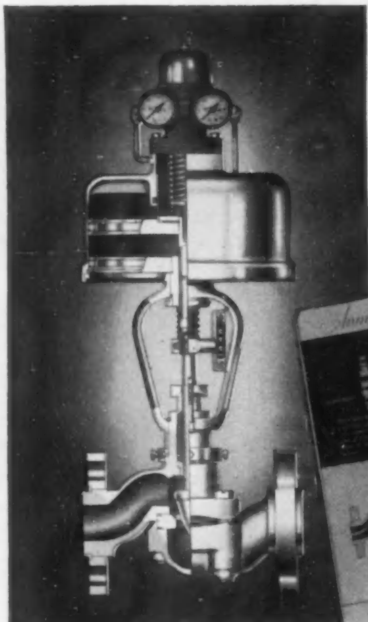
Honeywell

First in Controls



HOW ANNIN DOES IT.

The Best Way Yet in Process Control

SPLIT BODY CONSTRUCTION . . . SINGLE SEAT DESIGN
No other process control valve offers the advantages in economy and adaptability as that provided by the Annin valve. The split body eliminates pockets and shoulders that create undesirable turbulence and accumulated solids, reduces erosion and allows consistent flow behavior with a wide range of fluids under all conditions.

Superior body design permits conversion in any alloy from the basic Globe Body to Corner, Angle or 3-way construction.

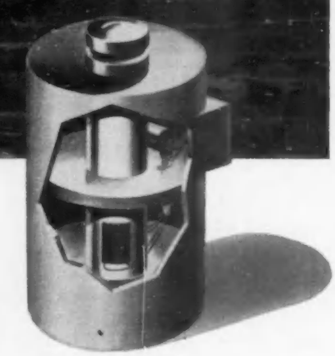
OPERATORS
Three basic Annin operators bring new and improved performance. The DOMOTOR operator is the most responsive, precise positioning and fastest pneumatic operator available... Electro-pneumatic or pneumatic CYLINDER operators, for remote shut-off applications, are designed to withstand continuous "on-off" operations... MANUAL operators, for precise throttling of flow rate and tight closure.

INTERCHANGEABILITY OF COMPONENTS
Applications unlimited are provided by interchangeability of Annin component features. Three types of operators, and five types of packing assemblies (plain extension, bellows seal, doolseal, cooling fin and standard) are interchangeable on one yoke and one body.

SEND FOR THE ANNIN CATALOG—
AN ENCYCLOPEDIA OF VALVE EXPERIENCE AND LEADERSHIP

SIMPLICITY IN DESIGN AND MAINTENANCE
The advantages of Annin single seat, split valve bodies, coupled with the design characteristics of Annin Domotor and other operators, provide control engineers with valves that can be installed without compromise in materials, response, tight closure, piping flexibility and dependability... making possible a reduction of parts from 50% to 75%, lower initial cost, lower spare parts inventory, lower maintenance.

THE ANNIN COMPANY
Division of The Annin Corporation
1040 S. Vail Ave., Montebello, California



Rocket engine thrust— precision measured by B-L-H Load Cells

It takes rugged, yet highly responsive, instrumentation to measure the explosive thrust of a rocket engine on test. B-L-H has solved this problem completely and accurately with its SR-4® Load Cells, mounted in a specially designed test stand of its own. The thrust of the anchored engine is exerted against the load cells. Instrumentation, which can be located at some point remote from the stand, gives moment-by-moment visual readings on dial indicators—or makes records of the performance on graphic recorders, digital printers, computers, etc.

Electronic transducers offer you the answer to virtually any testing or research problems involving tension, compression, torque, etc. With appropriate instrumentation, they can also determine center of gravity, weigh loads at rest or in motion, control batch and continuous processes, and record all data required. Long-term accuracy is within ± 1/10%, repeatability within ± 1/20%.

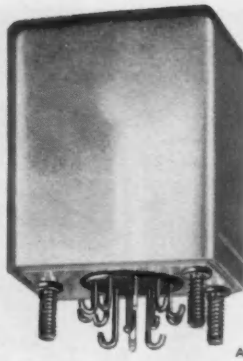
For more information on B-L-H electronic transducers—load cells, pressure cells or torque meters—ask to have one of our field men call, without obligation. And write to Dept. 6-G for a copy of Bulletin 4300.

BALDWIN · LIMA · HAMILTON
Electronics & Instrumentation Division
Waltham, Mass.
SR-4® strain gages • Transducers • Testing machines

BALDWIN BLH LIMA-HAMILTON

NEW RBM

BHSM and BHSM HT TYPES

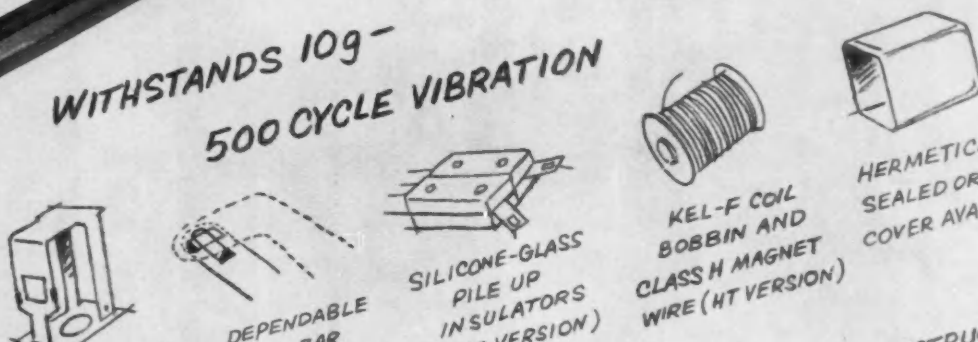


Actual Size

Miniature Hermetically Sealed Relays

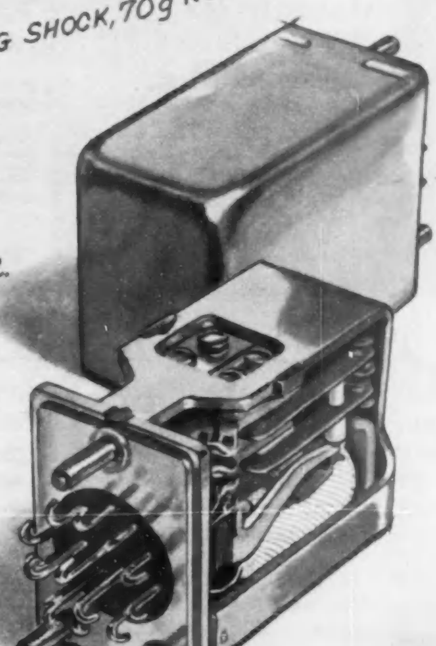
The reliability of this relay under severe conditions of vibration and shock has been field-proven in many applications. It is another example of how R-B-M's production maturity and complete facilities can eliminate many of your engineering problems.

WITHSTANDS 10g – 500 CYCLE VIBRATION



OPERATING BENEFITS

- 30g OPERATING SHOCK, 70g NON-DESTRUCTIVE
- 125°C OPERATING AMBIENT
- TEMP. RANGE: 22700 BHSM TYPE, -55°TO +85°C; 22800 BHSM HT TYPE, -65°TO +125°C
- COIL UP TO 130V.D.C.: SENSITIVITY 0.2W. MIN. PER POLE; MAX. COIL DISSIPATION 3.75 W.
- CONTACTS–MAX. 4 PDT 3 AMP. AT 32 V.D.C. OR 115 V.A.C. (NON-INDUCTIVE)
- SPECIAL CONTACTS AVAILABLE FOR LOW LEVEL OR DRY CIRCUIT APPLICATIONS
- APPROX. WEIGHT - 3.25 OZ.



Consult your local RBM Product Application Engineer or write for Bulletin BHSM-1.

RBM Division

ESSEX WIRE CORPORATION, LOGANSPORT, INDIANA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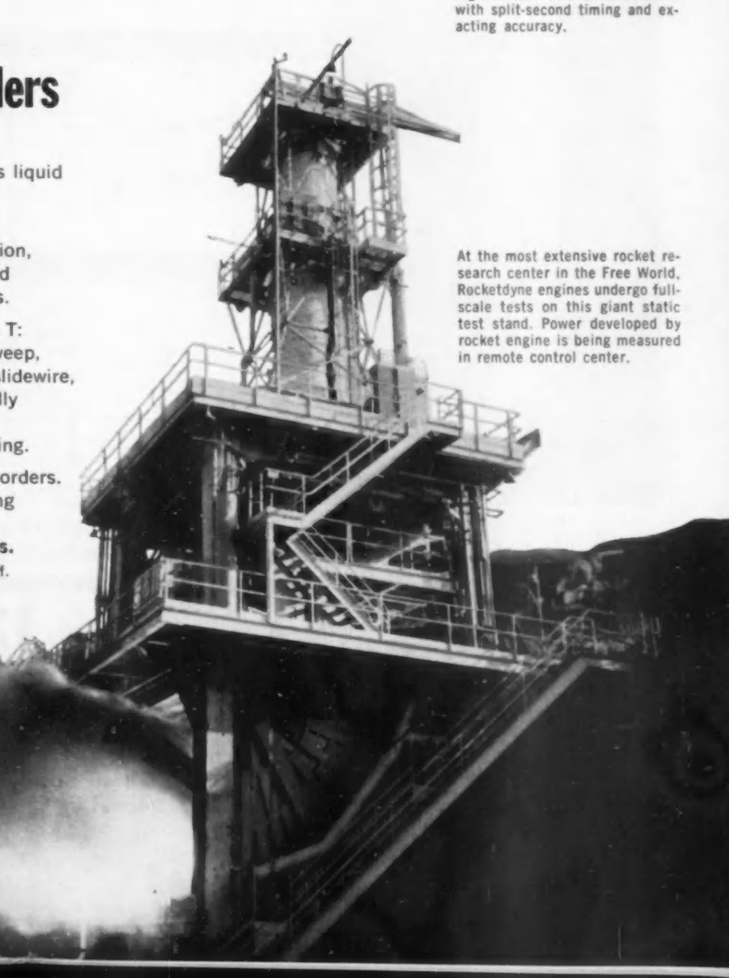

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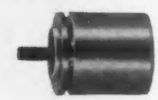
Oster

	SIZE 8	SIZE 10	SIZE 11	SIZE 15	SIZE 18
Oster Type	8-5001-00	10-5052-00	11-5101-00	15-5153-00	18-5201-00
Electrical Characteristics:					
Frequency (cps)	400	400	400	400	400
Torque at Stall (oz. in.)	.15	.30	.63	1.45	2.35
No Load Speed (rpm)	6500	6500	6500	5200	5200
Speed at Half Torque (rpm)	4000	4000	4000	3200	3200
Time Constant (sec.)	0.03	0.015	0.016	0.017	0.013
Reversing Time (sec.)	0.051	0.025	0.028	0.030	0.022
Theo. Acceleration at Stall (rad sec²)	22500	45000	41500	31000	40000
Operating Temp. Range (°C.)	−54 to +125	−54 to +125	−54 to +125	−54 to +125	−54 to +125
Slot Effect	1.6v/26v	1.0v/36v	1.0v/40v	1.0v/40v	1.0v/40v
Duty Cycle	Cont.	Cont.	Cont.	Cont.	Cont.
Fixed Phase					
Voltage	26	115	115	115	115
R (Stall) Ohms	196	1270	1250	490	280
X (Stall) Ohms	183	1560	1780	890	570
Z (Stall) Ohms	268	2210	2175	1030	640
P.F. (Stall)	0.73	0.57	0.58	0.49	0.45
Effective R (Stall) Ohms	366	3840	3800	2160	1460
Parallel Tuning cond. for unity P.F. (Stall) Mfd	1.0	0.13	0.15	0.33	0.55
Control Phase					
Voltage	40/20	40/20	40/20	40/20	40/20
*R (Stall) Ohms	480	124	145	58	39
*X (Stall) Ohms	445	215	204	103	77
*Z (Stall) Ohms	660	248	250	118	86
*P.F. (Stall)	0.73	0.50	0.58	0.49	0.45
*Effective R (Stall) Ohms	910	495	430	240	190
*Parallel Tuning cond. for unity P.F. (Stall) Mfd	0.4	1.4	1.3	2.9	4.1
Mechanical Characteristics:					
Rotor Inertia (gm. cm²)	.47	.47	1.07	3.3	4.0
Weight (oz.)	1.2	2	4.5	8	14
Mounting Type	Synchro	Synchro	Synchro	Synchro	Synchro
Motor Length	.863	.672	1.703	1.625	2.03
Type Shaft	Pinion	Pinion	Plain	Plain	Plain
Shaft Extension	.375	.218	.437	.540	.540
Outside Diameter	.750	.937	1.062	1.437	1.750
Type Connection	Leads	Terminals	Terminals	Terminals	Terminals

*For 40v connection



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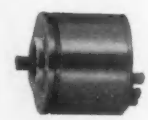

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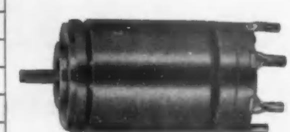

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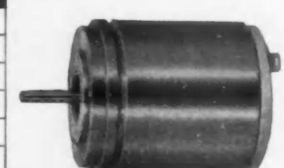

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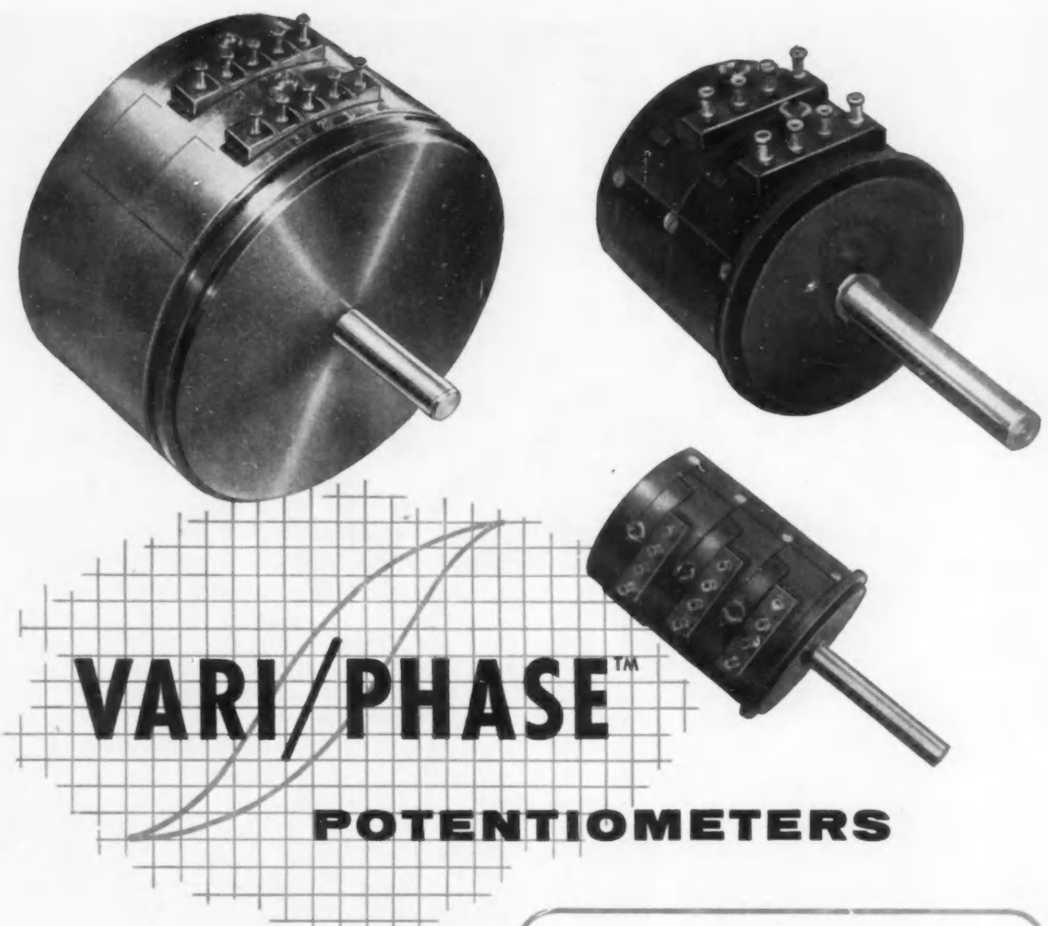

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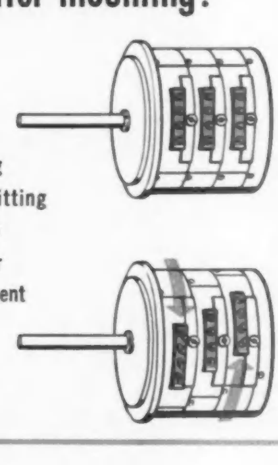

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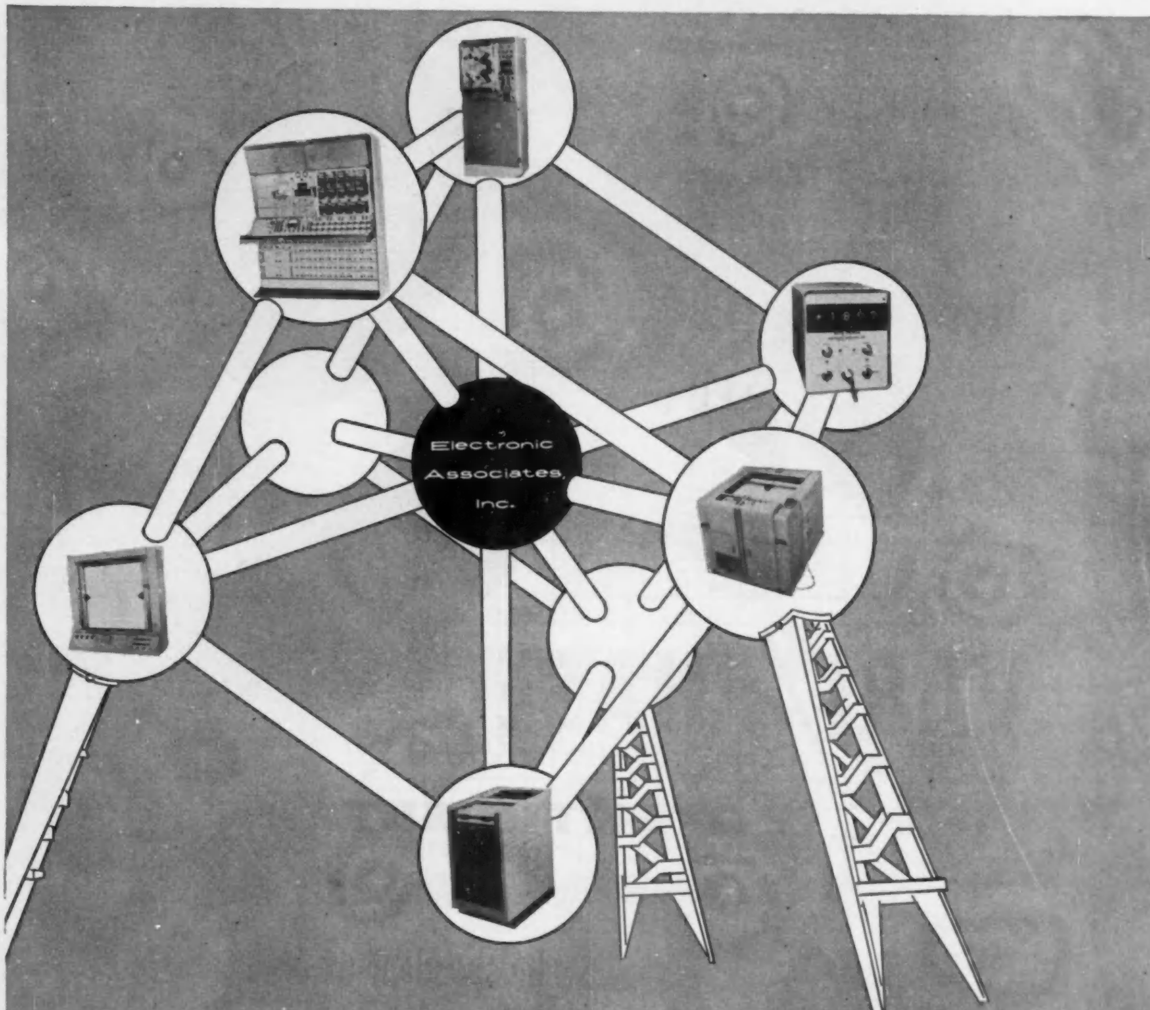

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The Japanese Boom in Automatic Control

Japan, in the midst of a spectacular industrial boom, is rapidly bringing itself up-to-date on automatic control techniques. Last month, Kazuto Togino, chief researcher at the Government Mechanical Laboratory in Tokyo, sent this on-the-scene report of activity in instrumentation and control.

Slow start

"Concentrating their energy on post-war construction, Japanese engineers didn't really start in automatic control until 1953. At that time we were amazed at the tremendous strides that had been made in the U. S. We began to try and catch up.

"First applications were automatic controls for furnaces in thermal power plants and iron and steel mills (by 1957, Japanese steel production had reached 12 million ingot tons, ranking the country sixth among the world's steel producers); then, automaticity was applied to the process industries. During this early period, controllers were imported from U. S. manufacturers such as Leeds & Northrup, Foxboro, Taylor Instrument, Bailey Meter Co. and Minneapolis-Honeywell. New processing plants were built with American technical aid.

"Next step was manufacturing controls in Japan. A number of local companies signed licensing arrangements with U. S. instrument and control makers. The agreement between the Yamatake Keiki Co. and Minneapolis-Honeywell is credited by many Japanese with being one of the most important factors in stimulating the use of automatic controls in Japan.

Process controllers

"Today there are nearly 20 Japanese companies making pneumatic, hydraulic, and electronic controllers. Many of these work under license to U. S. firms, but some are using Japanese designs. To date most of the big control projects in Japan have been accomplished with American technical help, but now Japanese control engineers are starting to come into their own.

"For example, the control systems for the new, highly automatic paper mill of Oji Paper Co. at Kasagai was designed by Japanese engineers. And although some controllers were imported from the U. S., over half were made in Japan.

Computing-control study

"Computing-control for process industries is another area that has caught the interest of Japanese engineers. Almost 20 researchers are at work in the field. They've been handicapped, to some extent, by the lack of commercially available Japanese

computers. But that picture is changing rapidly. Some users have imported IBM or Remington-Rand computers. A couple of Japanese companies have started making data-loggers; none is yet completely in use.

"Tape- and card-program control has not yet been put to use by Japanese industry. Here at the Government Mechanical Laboratory, there are three projects under way in numerical control of machine tools. We expect that such research by Japanese tool makers will become increasingly active next year. But in Japan, because the aircraft industry is so small, there is no urgent pressure to develop numerical controls. (Typical aircraft activity: Kawasaki Aircraft Co. recently signed a $22 million agreement with Lockheed Aircraft Service Overseas, Inc., to build P2V-7 Neptune antisub patrol planes for Japan.)

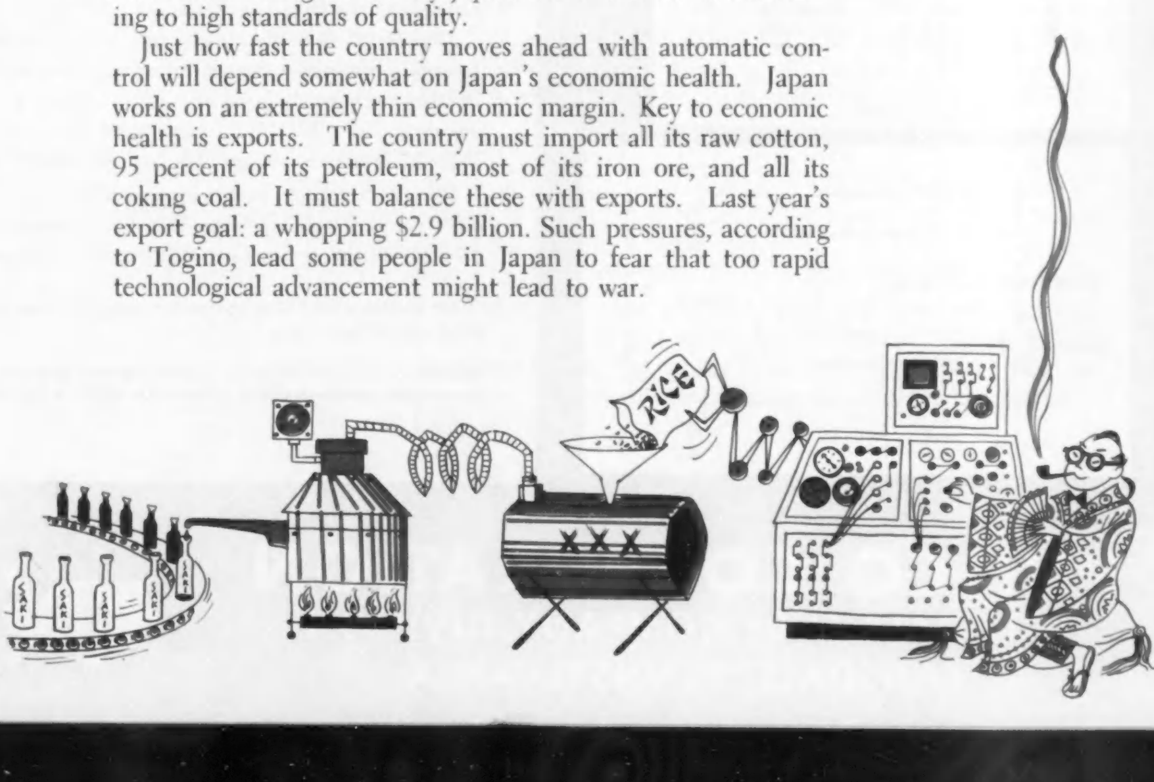
"Static switching elements are being sold by the Yaskawa Electric Mfg. Co., Ltd., under the tradename of Logit and Thypatron. Logit, using a rectangular loop core, is the same as Westinghouse's Cypak.

Two years behind

"'Overall, I would say that domestic-made instruments and automatic controllers are up to the technical standards of more advanced countries; in fact, some of this equipment is of superior quality. The gap between the theory of process control and its application is being reduced. On a theoretical level, I think that we Japanese engineers are about two years behind the countries of the West."

Control engineer Togino points out that Japan's low cost of labor does not encourage the use of automatic controls. Still, Japanese industries are looking to such controls for high speed, high reliability, and high quality. High product quality is a postwar trend in Japanese goods. In the 1930's that country built a reputation as a supplier of cheap, flimsy merchandise. But all that has changed. Today Japanese manufacturers are working to high standards of quality.

Just how fast the country moves ahead with automatic control will depend somewhat on Japan's economic health. Japan works on an extremely thin economic margin. Key to economic health is exports. The country must import all its raw cotton, 95 percent of its petroleum, most of its iron ore, and all its coking coal. It must balance these with exports. Last year's export goal: a whopping $2.9 billion. Such pressures, according to Togino, lead some people in Japan to fear that too rapid technological advancement might lead to war.



Control ENGINEERING

JULY 1958

Give and Take

Control engineers regularly take from a vast store of experience in measurement and control that has been accumulating for half a century. The trend is strongest in vertical industries; whenever urgent requirements in one of these industries produce innovations in components, methods of test, improved materials for construction, or more appropriate methods of application, the innovations cross over to other industries. In this way, control engineers give an amount of know-how at least equal to the experience they take.

Such is the case in nuclear processing, we learned recently at a conference on nuclear process instrumentation and control held at Gatlinburg, Tenn. by the Oak Ridge National Laboratory. Young science graduates with a smattering of the principles of measurement and control were plunged into nuclear problems. They found that the temperatures were extreme. That corrosive process fluids soon destroyed standard measuring elements and control valves. That process integrity was an absolute must, to avoid overwhelming expense and human catastrophe. In this environment the "youngsters" came up with solutions, perhaps because they didn't know that many of the problems had no solutions. Some are unnecessarily complex conglomerations, but there is a spin-off of sound innovations that other industries might find valuable. Here are some:

- primary measuring elements that perform at up to 1,500 deg F
- butterfly valves that will take the battering and corroding of slurries that cut through Stellite seats and plugs of plug valves
- an "eddy-current brake" for throttling the flow of liquid metals and slurries
- a three-dimensional flow-mapping technique
- methods of applying self-checking triplicated safety channels
- digital automatic start-up channels
- a diode matrix auctioneering unit.

Can you use any of them? If you can, drop us a note. We'll put you in touch with the men who have specified them and the manufacturers who can furnish them. And let us know, too, about some of your own problems in instrumentation, nuclear or not, that might be waiting on the proper innovation. If that innovation is accessible, we'll describe it in a future issue.

W. E. Vannah

Applying Part-Winding Controllers to Squirrel-Cage Motors

THE GIST: The trend to higher-horsepower squirrel-cage motors, to raise the output of industrial equipment such as chemical pumps and machine tools, has prompted increasing complaints about the effects of the large inrush currents caused by across-the-line starting. To these complaints are being added those of the power companies, which are concerned about the attendant line-voltage fluctuations, and the control-systems user, who finds that voltage dips can cause circuits to malfunction. This accounts for the renewed interest in increment starting, which is accomplished most economically by part-winding controllers.

J. SHEETS and W. G. McMICHAEL
General Purpose Control Dept.
General Electric Co.

Part-winding starting control (sometimes referred to as increment starting) is an inexpensive closed-transition method for starting squirrel cage induction motors. Its purpose is to reduce inrush current and thereby minimize the effects of motor starting on the voltage characteristics of the power supply system.

The part-winding starting method uses a motor whose stator windings for each phase are made up of two sections, rather than a continuous coil of wire. In operation, the motor is first energized with only one of the windings in each phase connected to the line. Then, after a suitable time interval, the second winding is connected parallel to the first winding. This is in contrast to the full-voltage starting method, whereby the total winding of the motor is connected directly across the line. Full-voltage starting usually results in currents that are approximately six times normal full-load running current. In contrast, motors started on part-winding initially draw about three or four times full-load motor current on the first step.

Part-winding starting has the following benefits:

1. It is the simplest of the reduced-kva starting methods.
2. It provides closed-circuit transition, meaning that it is not necessary to break the start circuit before making the run circuit.
3. It is usually the least costly of the reduced-kva starting methods.
4. It provides reduced-torque starting.
5. It can be applied to any standard 220/440-volt induction motor that is to be used on 220-volt systems.

But there are limitations to part-winding starting, too. These include:

1. The heating and mechanical stresses on the armature windings during starting are considerably more severe than they would be if the motor were started full-winding, full-voltage.
2. Part-winding speed-torque characteristics display a dip that makes it difficult to accelerate high-inertia loads to full speed on the initial winding.
3. Torque efficiency is the lowest of the reduced inrush methods. Torque efficiency is defined as:

$$E_T = \frac{\text{percent of full-voltage starting torque}}{\text{percent of full-voltage line current}}$$

4. Special dual-voltage motors are required for system voltages larger than 220 volts.

Part-winding starting should be considered wherever standard squirrel-cage motors and reduced-voltage starters giving 65-percent starting voltage are used. It has been used widely on air-conditioning pumps and compressors because of power-supply restrictions. Lately, however, its potential for industrial machinery drives has become of great interest. Two factors underlie this new trend. First, utility people are concerned about the swing to higher-hp motors throughout the industrial-machinery field because

FIG. 1.
Schematic of 3/3 controller for part-winding starting.

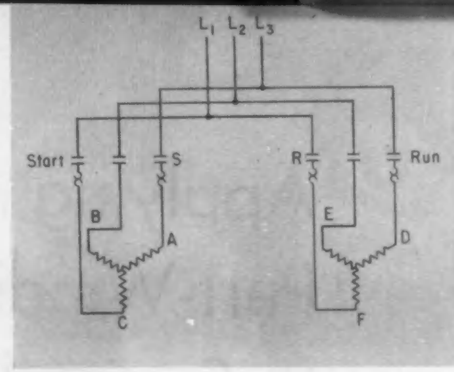
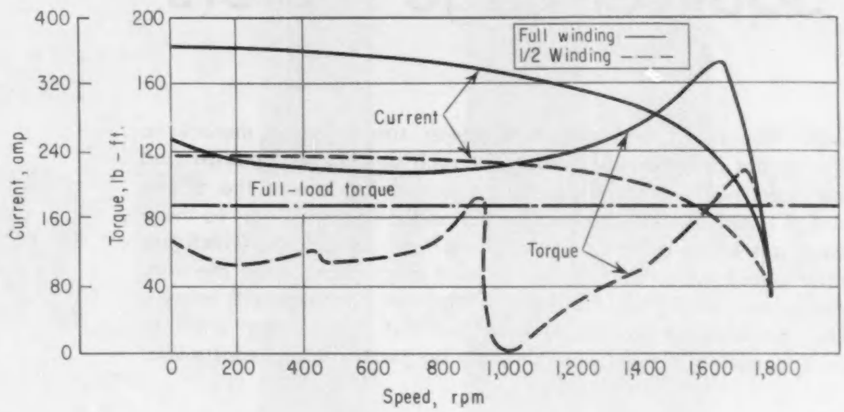


FIG. 2. Motor characteristics for one-half method of starting. For comparison solid curves show current and torque values when motor is started directly across the line. Note severe dip in the torque curve for one-half winding start.



of the current surges occurring when such motors are started across the line. Second, voltage dips are rapidly becoming intolerable in plants where there are machines with complex controls systems. Such controls may drop out of malfunction due to supply-voltage fluctuations. For these reasons, the use of step-starting for squirrel-cage motors is being encouraged for an increasing number of applications.

The majority of the opportunities for part-winding starting are on low-inertia drives. On high-inertia drives such as ball and hammer mills, it must be assumed that the load will not accelerate to full speed during the first step. Jogging of part-winding starting motors is therefore not encouraged.

3/3 and 4/2 pole controllers

There are two conventional control circuits for part-winding starting. The historic approach (sometimes called the "one-half" winding method) has been to employ two similar three-pole contactors, each of which connects an identical set of motor windings to the line, Figure 1. In this control circuit, contactor *S* closes, connecting windings *A*, *B*, and *C* to the line to produce the starting torque. After a time delay, contactor R closes, putting windings *D*, *E*, and *F* across the line. Now the full windings are energized and the motor assumes conventional operation. Contactors S and R each carry only one-half of the line current. Therefore, the contactors used in this type of control need be rated at only one-half the horsepower of the motor.

In this starting method, one-half of the motor windings are in the circuit in a symmetrical Y connection. Since only half of the total number coils are active, the winding will produce a torque dip at approximately half speed. In some cases, this dip may be so severe as to touch the zero-torque line. Figure 2 shows the speed vs. torque and line current vs. torque characteristics of a typical motor for both across-the-line and 3/3-pole part-winding starts.

One way to overcome the disadvantages that can result from severe torque dips is to apply the control scheme shown in Figure 3; this is known as the "two-thirds" method. This variation makes use of a four-pole starting contactor and a two-pole run contactor. In operation, the start contactor closes to energize windings A and B in series and simultaneously, windings D and F in series. Again, after a suitable time delay contactor R closes, completing the circuit to windings C and E. Now all of the motor's windings are energized.

It can be seen that with this arrangement two-thirds of the motor coils are in the circuit during the starting cycle. Therefore, the torque dip caused by the harmonic fields will be considerably less (see the speed-torque curve of Figure 4). Some small or low-speed induction motors may require the one-half method of connection. However, even here the standard 4/2 pole controller can be used when it is connected as shown in Figure 5.

Motor connections

The above examples have shown Y-connected motors having six leads. For flexibility, it is desirable that

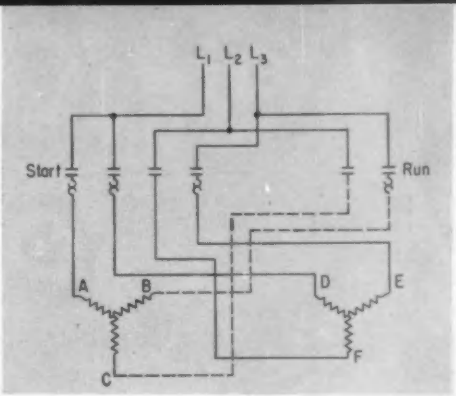
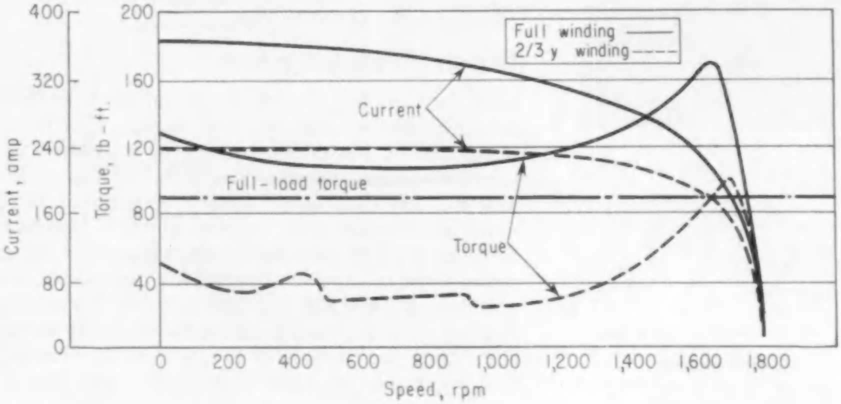


FIG. 3. Schematic of 4/2 controller for two-thirds winding start.

FIG. 4. Solid curves show current and torque for across the line start. On a two-thirds winding start, torque is reduced as well as current. However, note absence of dip.



the standard 4/2 pole controller be able to control both Y- and delta-connected motors having either six or nine leads. Actually it can. The schematic diagrams and explanatory table in Figure 6 show the control connections that are to be made for any of six possible combinations of motor connections and number of leads. It should be noted that for nine-lead motors, it will be required to connect together certain motor leads at the motor terminal box.

The National Electrical Manufacturers Association recently listed part-winding starters as "— Class A magnetic controllers for squirrel-cage motors of the type in which a part of the winding is connected to the supply lines for a first starting step and an identical winding is then connected to the supply lines as the second step." The ratings recommended by NEMA are shown in Table H, which covers a total of five different controller sizes rated at from 15 to 400 hp on 440-550 volts.

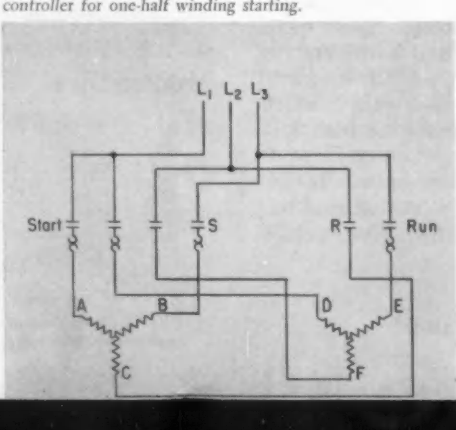
windings will result in a minimum of line disturbance and voltage dip. In a large number of cases, however, the load will require practically full motor torque before accelerating to rated speed, and in these cases the motor will not be able to accelerate to full speed on the first step of the controller.

The natural tendency of the control engineer is to specify an increase in the time delay setting of the switchover relay in an attempt to obtain full acceleration during the first step. However, if this expedient is carried too far, it will result in tripping of the overload relays. If the motor will not accelerate on the first step, it is best to set the relay to switch from start to run in a relatively short time period, in the order of 1 to 2 sec of delay. If it is expected that the motor will be able to accelerate the load in a reasonable period of time, the timer may be set for a delay of as much as 10 sec. In any case, however, the time delay must be given careful consideration.

Timer setting

The adjustment of the time-delay relay that switches the motor from start to run conditions is important to satisfactory application of part-winding starting controls. Most applications require the motor to accelerate to full speed under the first step. If this is possible, the switchover to the full

FIG. 5. Adaptation of a 4/2 controller for one-half winding starting.



Increment vs. full acceleration

In the majority of applications of part-winding techniques, the motor accelerates to full speed on the first step. Operation in this mode is termed "full-acceleration" starting and is distinguished by the fact that there is no addi-

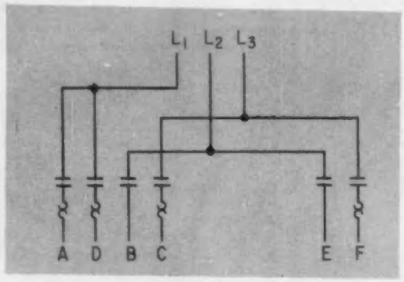


Table I part winding schemes		Lettered terminals in panel					
		A	B	C	D	E	F
1/2 y or Δ	6 leads	T_3	T_8	T_7	T_9	T_2	T_1
1/2 y	9 leads ○	T_3	T_8	T_7	T_9	T_2	T_1
1/2 Δ	9 leads □	T_3	T_8	T_1	T_9	T_2	T_7
2/3 y or Δ	6 leads	T_3	T_2	T_7	T_9	T_8	T_1
2/3 y	9 leads ○	T_3	T_2	T_7	T_9	T_8	T_1
2/3 Δ	9 leads □	T_3	T_8	T_7	T_9	T_2	T_1

○ Connect terminals 4, 5 and 6 together at terminal box.

□ Connect terminals 4 and 8, 5 and 9, 6 and 7 together in three separate pairs at terminal box.

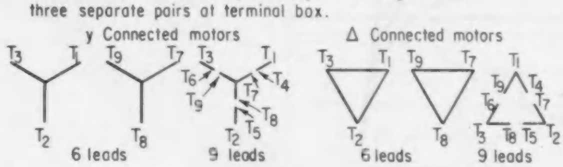


FIG. 6. Table of connections for adapting 4/2 controller for part-winding starting of motors having any combination of connections and leads.

Table II—NEMA Ratings for Part-Winding Controllers

Size	8-Hour Open Rating of Contactors, Amp	Controller Horsepower	
		220 Volts	440–550 Volts
1 PW	25	10	15
2 PW	50	30	50
3 PW	100	60	100
4 PW	150	100	200
5 PW	300	200	400

tional current inrush at the switchover from start to run conditions. Only full-acceleration starting will overcome the voltage dips that are objectionable to utility companies and control users for the reasons mentioned previously. Another mode of operation, "increment starting", is employed in certain applications. Here the motor does not reach full speed during the first step, and hence total inrush current is not appreciably reduced: it is merely divided into increments. This is brought out in Figure 7, which shows the curves of speed vs. current for both full-acceleration and increment starting.

In cases where full acceleration cannot be expected during the first step, increment starting has an advantage over full-voltage starting. One specific objection to full-voltage starting is that it will result in light flicker within the building or plant. Tests have shown that flicker decreases appreciably if the dip in light intensity can be broken into one or more steps. In other words, a dip of 6 percent in light intensity is objectionable, while a dip of 3 percent followed by an additional dip of 3 percent 2 sec later is not objectionable. For this reason, a motor using an increment-starting control will have a tolerable effect on illumination levels; this same motor started on full voltage would cause objectionable light intensity dips.

Branch circuit protection

For part-winding controllers, the rating of the overload-relay heater need be only one-half that of an across-the-line starter for a motor of equivalent rating. This means that the cross-sectional area of the heater is less than would usually be specified for a motor drawing the same full-load current. However, the branch circuit protection on the line ahead of the starter must be capable of permitting full inrush current (about six times full load current) during the starting cycle without removing the motor from the line. Thus, the capacity of the overload heaters will be considerably less than the rating of the branch-circuit protection.

Unless special precautions are taken to coordinate the motor branch circuit protection with the actual overload relay heaters chosen, the overload relay heaters will tend to act as fuses upon short circuit conditions. The ideal answer, of course, is two sets of fuses. This is often not economical. In most cases the use of dual element fuses rather than NEC fuses will result in better protection of the overload relay heaters.

In summary, part-winding starting can usually be applied to advantage on low-inertia loads by the proper choice of controller connections and throw-over timer settings. When successfully applied, this method will result in a low-cost reduced current inrush to meet the requirements of most power companies and to minimize disturbance on plant buses feeding complex control panels.

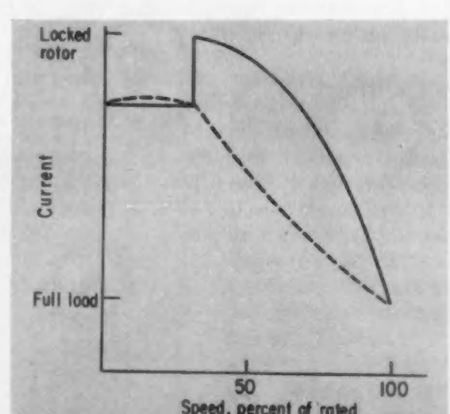


FIG. 7. Comparison of current drawn during starting with conventional-increment and full-acceleration methods.

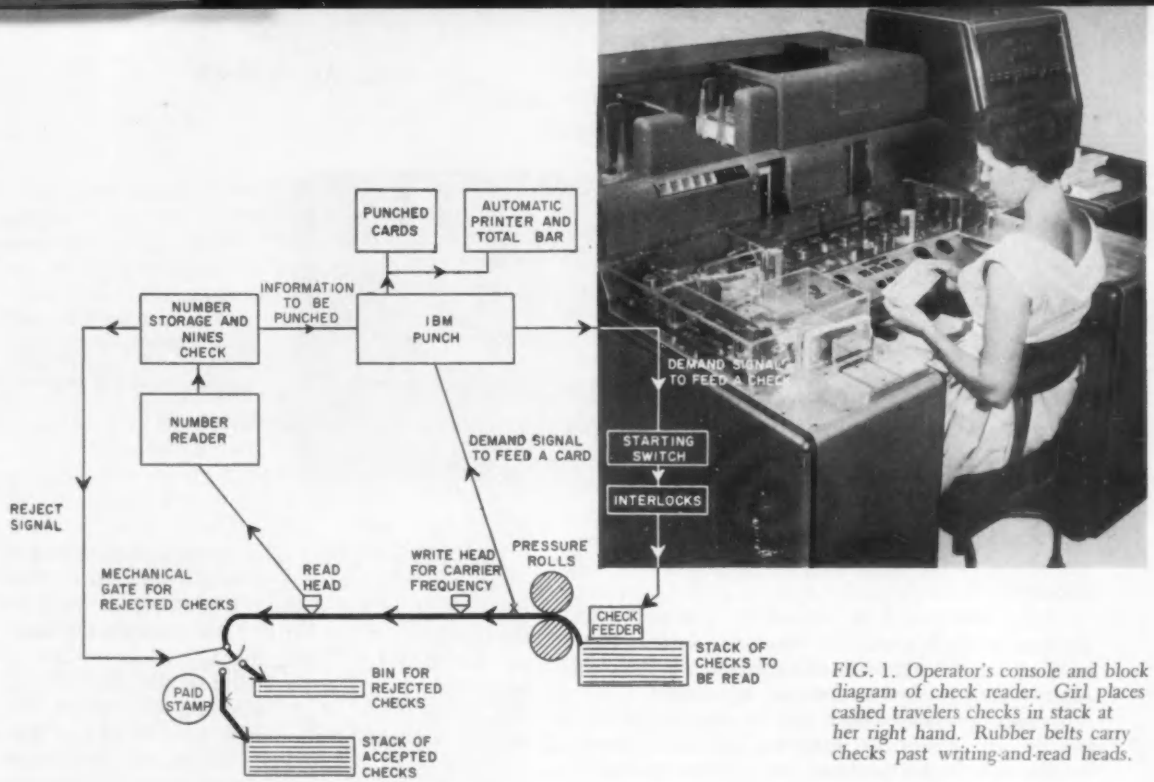


FIG. 1. Operator's console and block diagram of check reader. Girl places cashed travelers checks in stack at her right hand. Rubber belts carry checks past writing-and-read heads.

Magnetic Reader Speeds Travelers-Check Processing

K. R. ELDREDGE
K. W. GARDINER
F. J. KAMPHOEFNER
P. E. MERRITT
C. M. STEELE
Stanford Research Institute

Bank of America is using a magnetic reader to process cashed travelers checks. Here is a description of how the device works, the circuitry that converts Arabic numerals to electric signals, and the techniques which prevent errors.

To speed up the processing of travelers checks after they have been cashed, the Bank of America has installed an electronic reader developed at the Stanford Research Institute Control Systems Laboratory. Using a magnetic reading head, the machine senses the serial number and amount of the check—printed in a special magnetic ink. It then performs an arithmetic check, punches out a card that can be reconciled with similar cards prepared when the checks were issued, and finally totals the amount of checks handled. In operation since June 1957, the machine has processed six million travelers checks. And the machine has rejected as unreadable less than $\frac{3}{4}$ percent of the items.

Handling travelers checks lends itself to automatic operation. For one thing, processing is seasonal. The majority of checks are cashed during the summer months when vacationers are on the move. That means bank clerks trained to handle reconciliation of travelers checks have little chance to use their training during the long time lags between peaks. The electronic reader can accommodate the seasonal load without difficulty. And it releases per-

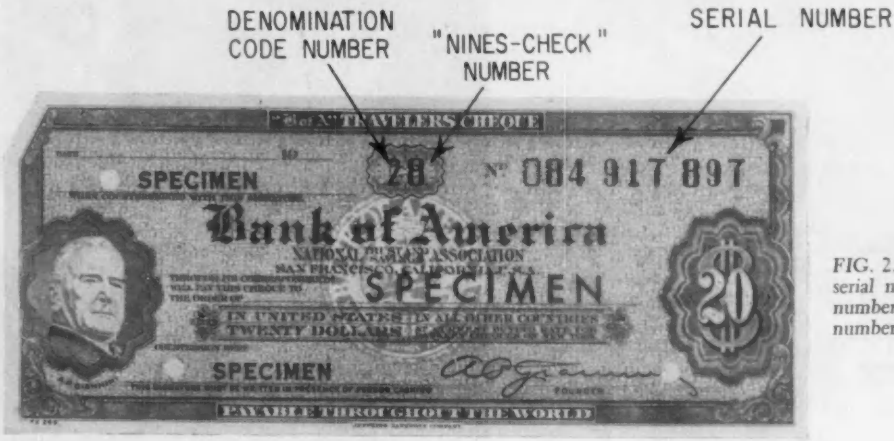


FIG. 2. New travelers check with serial number, denomination number, and "nines-checking" number printed in magnetic ink.

sonnel within the bank for work of greater seasonal stability.

Checks are issued to the seller in large blocks. Since each block contains a sequence of serial numbers, an equivalent series of cards can be punched automatically with conventional equipment.

Frequently while a check is in circulation it is written on, or subject to stamping and defacement. For this reason the machine does not use an optical scanner; the magnetic head reads the Arabic numerals directly, obviating auxiliary coding. Because of the design of the reading head, misregistration of the printing on the checks does not affect the performance of the reader. The numerals can be displaced vertically as much as plus or minus $\frac{3}{8}$ in., or horizontally by an inch or two, without impairing readability. If the numerals are skewed (by defective printing or improper operation of the mechanical feeder) as they pass the reading station, the machine will not reject them until the skew is more than $\frac{1}{4}$ in. in the 6-in. length of the check.

When the checks are returned from circulation, their order, of course, is random. Before the check reader was installed, new cards corresponding to the returned checks had to be punched and reconciled with those prepared when the checks were issued. The electronic reader does away with the manual punching operation and reduces the chance of error.

Some errors, of course, will arise as the machine reads. But when they occur, the checks are rejected by the checking circuits. The machine's reject rate of less than $\frac{3}{4}$ percent compares favorably with the 3-percent card-spoilage rate of the manual operators.

There are five reasons why the error rate is low:

1. The Arabic numerals are stylized for maximum differentiation between waveforms for the 10 numerals (see Figure 3).
2. A single error within a character code results in a forbidden combination, not another character.
3. A parity check and forbidden-digit check are used in the relay-storage matrix.
4. The storage register must fill to exactly 11 digits per check. A dropped digit or extra digit causes the check to be rejected.
5. A "nines-check" digit is used.

Here is how the digit proving works. Each check is printed with an extra digit that is selected so that the sum of all the digits is a multiple of nine. In the travelers check of Figure 2, for example, the serial number is 084 917 897; the $20 denomination is represented by a 2 at the center of the check. Thus, the "nines-check" digit, which is printed to the right of the denomination digit, must be an 8 so that the sum of all of the digits will be 63, a multiple of nine. The machine automatically rejects all checks that do not satisfy the nines-check relationship. It would also be possible to use the check digit as an error-correction device (to fill in the correct number whenever a single digit is missed by the reader). This would improve the reject rate with only a slight sacrifice in error-rate. It was not used here because the reject rate is satisfactory without it.

Operating the machine

The main function of the machine operator is keeping the feeder console supplied with checks and the punch supplied with cards. The operator places a stack of travelers checks in the feeder position and presses the starting switch. The machine picks up checks from the stack, reads them, and punches cards at the rate of 100 per minute—the maximum speed of the punch. A faster punch could operate at 10 times this rate without changing the velocity of the check transport or the reading rate of the electronic circuitry. The reader is synchronized with the card punch so that each check is fed from the stack with an adequate lead time for the punching cycle.

The check passes through a set of pressure rolls that smooth any bad wrinkles. It then actuates a track switch that produces a "demand" signal for a card to be fed by the punch. As the check passes a write-head, a 15-kc carrier frequency is impressed on the magnetic printing. At the reading station, the signals from the read-head are amplified so that the numerals can be decoded, checked for errors, and put into storage. If the error-checking circuitry indicates that the check has been correctly read, it is automatically stamped PAID and stacked with accepted checks. If the full number has not been read correctly, a signal diverts the check to a reject bin.

Whether the check is accepted or not, a card is punched with the requisite information. Cards corresponding to rejects are offset-stacked (a hole in a separate column indicates a reject). A mechanical printer reads the serial number and denomination directly from each card immediately after it has been punched, and prints a list and dollar total for each batch. (The list includes rejects as a convenience in checking.) This list can be compared with a similar list received by the central office.

Extensive interlocks are incorporated to make the machine very nearly foolproof. The machine will stop feeding if it runs out of checks or cards, if a check or card jams, if a supply voltage fails, if the feeder's vacuum system fails, if the safety covers are lifted, or if a bin for punched cards becomes overfilled. A failure of the reading, checking, or storage circuitry sends all checks to the reject bin.

Reading magnetic numerals

The numerals used on the travelers checks have been styled to reduce the complexity of the decoding circuitry and to maintain a high degree of decoding accuracy. The interpreter section of the electronics identifies the character on the basis of high and low level amplitudes of the modulating signal at predetermined time intervals. This internal coding takes the form of a serial binary code using six binary bits. For example, the code for the numerals six is the series high-low-low-high-high-low, reading from right to left. A coding of this type has been incorporated in the numerals font.

The width of the numerals is another means of identification, three different widths being employed. The full-width numerals are the zero, three, four, five, seven, and eight. In the second group, 5/6 of full width, are the two, six, and nine. The numeral one occupies 4/6 of full width. The serial binary code plus the width information has been defined as an eight-bit binary code. Numeral six is completely represented by 10011010. In the eight-bit code, each number differs from all other numbers by at least two binary bits, thus making it possible to detect single errors in the code.

To convert the numerals to electrical signals, a fixed-frequency sine wave is magnetized on the magnetic ink via the write-head. When the magnetic ink passes the read-head the sine wave is detected. The detected wave is amplitude modulated by a function dependent on the amount of magnetic medium under the read-head air gap. If the magnetic medium is characterized by a strip passing perpendicular to the air gap, the amplitude of the output sine wave will be proportional to the width of the magnetic strip. Using the approximation that amplitude is directly proportional to the length of magnetic material under the read-head air gap and the fact that the head completely overlaps the numeral, the wave shape representing each numeral can be graphically constructed (Figure 3).

Both the read- and write-heads are single-channel heads, wide, with conventional pole construction. The wide track width overlaps the printing, and allows considerable variation in registration of the 0.210-in.-high numbers without changing the output signal. The write-head current is sufficiently large to completely saturate the magnetic ink so that the output signal from the read-head is independent of recording current.

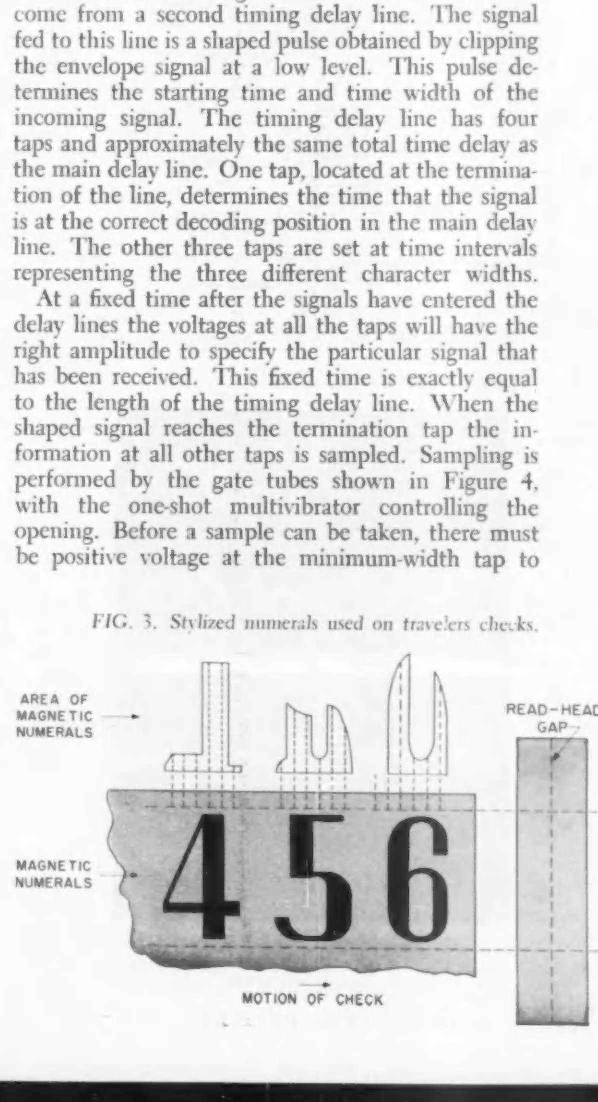
Decoding circuitry

Figure 4 shows a block diagram of the decoder section. The electrical signal from the read-head is amplified and demodulated to obtain the envelope which is characteristic of a particular number. The demodulated signal (Figure 5) is then introduced into a tapped delay line, which stores it for a full character-width in time. The associated timing circuits are synchronized with this delay line, making the high-low information simultaneously available from the six taps at readout time. The signals from the six taps are fed to difference amplifiers for comparison with a reference level.

The read-out timing and the width information come from a second timing delay line. The signal fed to this line is a shaped pulse obtained by clipping the envelope signal at a low level. This pulse determines the starting time and time width of the incoming signal. The timing delay line has four taps and approximately the same total time delay as the main delay line. One tap, located at the termination of the line, determines the time that the signal is at the correct decoding position in the main delay line. The other three taps are set at time intervals representing the three different character widths.

At a fixed time after the signals have entered the delay lines the voltages at all the taps will have the right amplitude to specify the particular signal that has been received. This fixed time is exactly equal to the length of the timing delay line. When the shaped signal reaches the termination tap the information at all other taps is sampled. Sampling is performed by the gate tubes shown in Figure 4, with the one-shot multivibrator controlling the opening. Before a sample can be taken, there must be positive voltage at the minimum-width tap to

FIG. 3. Stylized numerals used on travelers checks.



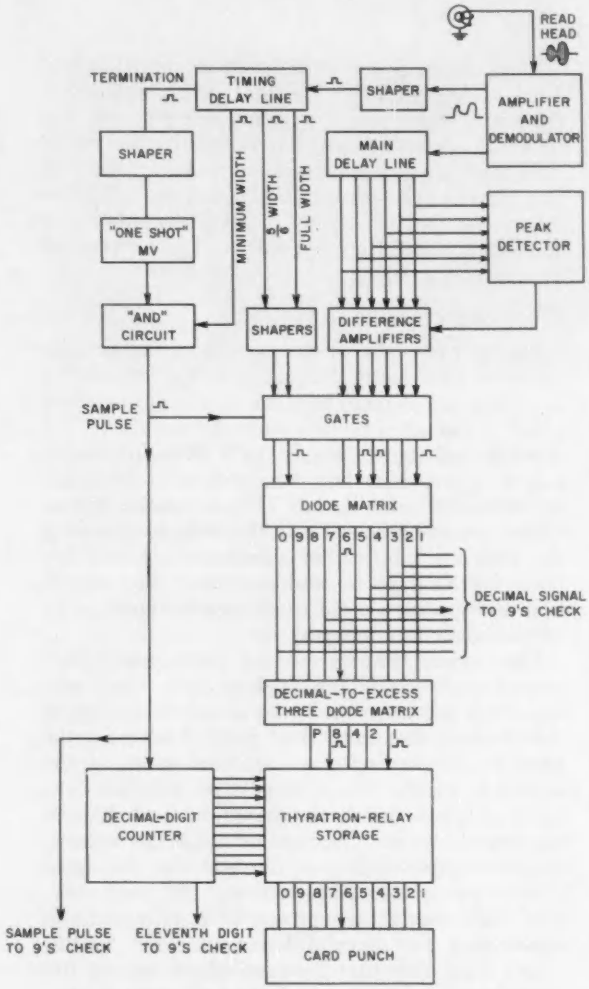


FIG. 4. Block diagram of "nines-check" section.

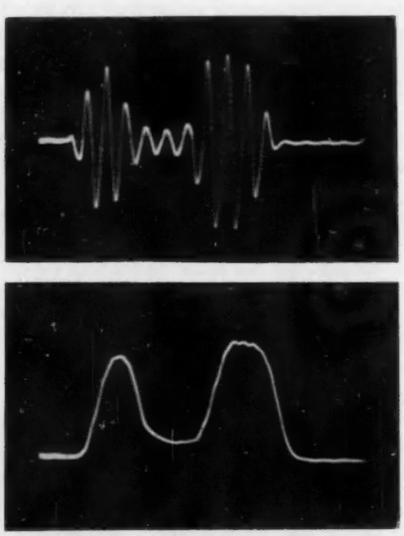


FIG. 5. Demodulated signal is characteristic of numeral. Note that time base is reversed from Figure 3 because check is read from right to left.

satisfy an AND circuit. Since noise signals here are characteristically shorter than the numeral signals, false samples are easily eliminated.

The six taps of the main delay line are connected to difference amplifiers for the purpose of comparing the voltages against a reference. The reference voltage used is the largest voltage at any one of the six taps at sample time. The necessity of comparing against a reference is due to a variation in ink density during printing: the signals will all have the correct shapes but the amplitude factor may vary. The peak value of the sample points, selected in the peak detector, is proportional to this amplitude factor and supplies the signal-normalizing reference.

If a sample-point voltage is greater than some fixed percentage of the reference voltage, the difference amplifier will pass a positive signal through the gate at sample time. Otherwise, no signal passes the gate. Each difference amplifier uses a different percentage of the reference to allow a maximum of signal variation. Any voltage may deviate from its expected value by 50 percent and still decode properly. At readout time, the gate outputs supply the high-low information in parallel binary form.

The two "width" taps of the timing delay line are connected to shapers, and when their output signals are gated, the width information is in binary form. After it is converted to its decimal equivalent, the received signal is ready for storage and checking.

Storage

Because the punch accepts information in parallel form, and because there are timing considerations, the incoming number sequence must be stored before it is transferred to the punch. To facilitate storage, the decimal signal is converted to a coded form by another diode matrix. The code used is the binary excess-three code with a parity check, stored by means of thyratron-controlled relays. Eleven banks of five thyratrons and relays store the 11-digit number. The binary digit from the matrix drives the control grid of the thyratron, while the signal which steps down the banks drives the suppressor grid. The stepping signal comes from the decimal digit counter, which counts each of the 11 digits in the serial number. When the thyratrons fire and pull in the relays, the relay contacts decode the binary form back to decimal. As the punch comes to the correct part of its cycle, the punch emitter connects the relay contacts to punch magnets for the card perforating operation.

9's check and 11-digit check

At the same time that the decimal number is being stored, it also undergoes two verification checks. One of these determines that a full 11 digits and only 11 digits have been received; this is accomplished using the 11th output of the decimal digit counter. The second check verifies that the sum of the serial number is a multiple of nine.

The nines check circuit is divided into two parts (Figure 6).

The first part produces a pulse sequence which has the same number of pulses as the numerical value of each received digit. When each of the 11 numbers on the check is scanned, this sequence is produced as follows: The incoming decimal signal is fed through a diode matrix, which converts the signal to a sixteens-complement binary code; that means the number to be coded is subtracted from 16, and the difference value is then coded in the familiar 8, 4, 2, 1 binary code. For example, when a 5 is received, the code from the matrix is 1011 ($16 - 5 = 11; 8 + 0 + 2 + 1 = 11$). The sixteens-complement code from the matrix then presets a four-section binary counter.

The reason for the sixteens-complement code can be seen by considering the number 5. This would be coded as an 11, and the 11 preset into the binary counter. Exactly five input pulses will then be required to step the counter to the end (16th position). This arrangement provides a means for obtaining the proper pulse sequence. Simultaneously with the decimal signal, a sample pulse indicates that the reading of the incoming signal has been made. The sample pulse triggers a flip-flop, which in turn releases the clamp on a multivibrator and allows it to free-run after a short delay. The output of the multivibrator triggers the four-section binary counter, and as it steps to the end, the flip-flop is switched back, causing the clamp to be reapplied.

During this cycle, the number of pulses produced by the multivibrator is equal to the decimal value of the incoming signal. Because the numbers zero and nine will add either nothing or a single multiple of nine to the total sum, the decimal signal for these two numbers prevents the clamp from being released, and no output pulses result. If a sample is taken, but because of distorted printing no decimal signal appears (a possibility because of the error-detection quality of the code used for designating characters), a sequence of 16 pulses is generated.

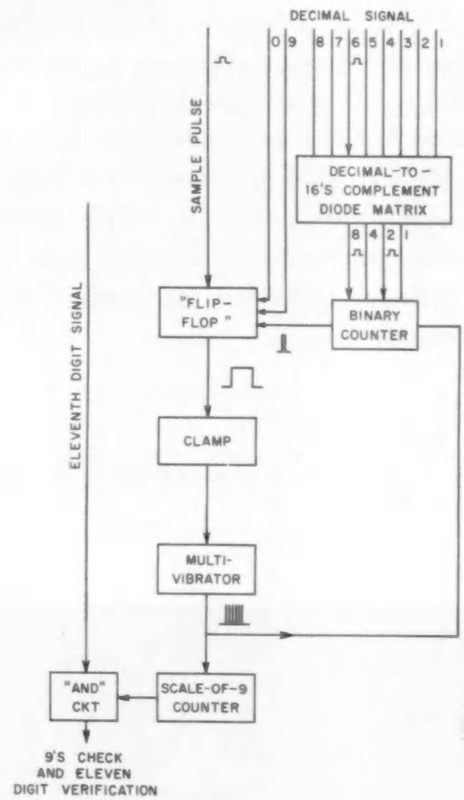


FIG. 6. Block diagram of decoder section.

The second part of the nines check circuit accumulates the multivibrator pulses in a scale-of-nine counter. At the end of the incoming number sequence, this counter must be in the nine position for the sum to be equal to a multiple of nine. An AND circuit using the output from the scale-of-nine counter and the 11th output of the decimal digit counter produces the final signal for the verification of the nines-multiple and 11th digit checks.

STANDARDIZATION IS UNDER WAY

A new system has been described recently for electronically reading numerals of conventional appearance that are printed in magnetic ink. The Arabic numeral style used with that system and shown here has been*

1234567890 ⑈⑆⑇⑉

recommended by the American Bankers Association as a new standard for all checks printed in this country, since it can be read equally well by the general public or by machines. When this recommendation is implemented, all personal and commercial checks will use these numerals to identify the writer's account number, branch number of his bank, transit routing numbers, and denomination.

The Bank of America's travelers check reader differs from the new system in that the decoding logic is less sophisticated and requires the printed numerals to be tightly controlled in order to make them readable by the machine.

Both of the above systems were developed jointly by the members of the Control Systems Laboratory, Stanford Research Institute. In addition to the authors, the following engineers made important contributions to the electronic portion of the project: F. C. Bequaert, W. C. Dersch, S. E. Graf, M. D. Marsh, and R. I. Presnell. The automatic document-handling equipment was designed by T. Hori, R. F. Newton, B. J. O'Connor, and P. H. Wendt.

* Automatic Input for "Business Data Processing Systems", K. R. Eldredge, F. J. Kamphoefner, and P. H. Wendt. Presented at Eastern Joint Computer Conference, December 1956.

On-Stream Control with an Infrared Analyzer

THE GIST: Increasing demands for direct measurements of product composition of process streams have led to greater use of analysis instruments in the closed-loop control of operating plants. In this case history, the authors describe an instance in which an infrared analyzer applied to reflux ratio has for the past four years successfully, reliably, and automatically controlled the product stream from a distillation column.

L. W. ADAMS, L. W. HERSCHER, and H. D. RUHL
The Dow Chemical Co.

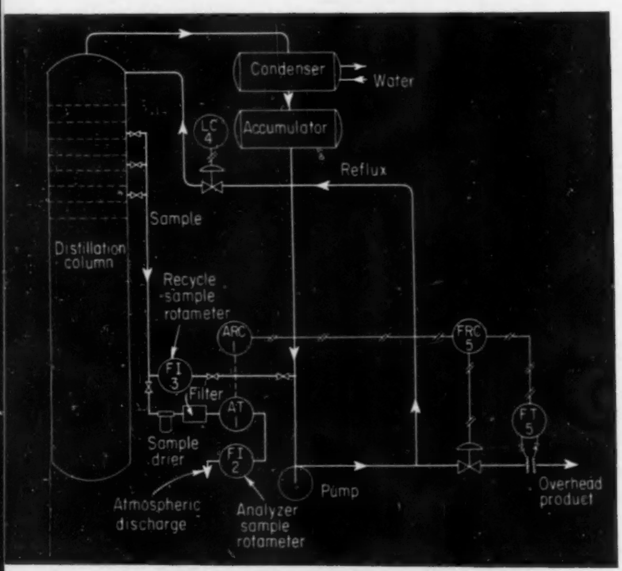


FIG. 1. The flow and instrumentation diagrams for a distillation process. Here the product-stream composition is under automatic control of an infrared analyzer.

A rather unique application of an infrared spectrometer-type continuous analyzer occurred in the control of a distillation column's overhead product. The problem was one of determining and automatically controlling small concentrations of o-ethyl toluene in a liquid stream of m- and p-ethyl toluene. Such an analysis called for a dispersive-type infrared analyzer, but at the time no such instrument was commercially available that would meet analytical and operational requirements. For this reason, The Dow Chemical Co. designed and built its own infrared spectrometer stream analyzer (Refs. 1 and 2).

Because of the hazardous-area location, the analyzer's optical system and associated electrical components must be enclosed in a standard explosion-proof housing—but without sacrificing resolving power or reducing output signal from the detector. A large output signal permits a smaller amplifier gain, which thereby increases the instrument's stability and reliability. The sampling system, designed to minimize cell maintenance, provides dried and filtered sample to the analyzer at a slight static pressure. The filter uses readily available filter-paper discs, yet keeps sample volume to a minimum.

Figure 1 shows the distillation column, the analyzer, the analyzer-controller, flow-controller, and the sampling system. The sample stream is taken several trays from the top of the distillation column and is analyzed for the o-isomer; then the analyzer recorder-controller *ARC*-1 repositions the set-point of the overhead flow recorder-controller *FRC*-5. Thus, a deviation from nominal of the o-isomer causes a change in product flow which effects a corrective change in the reflux ratio to maintain desired stream composition.

The sample stream is taken out 125 ft above the column's base and, although the column operates at a vacuum, there is more than adequate head to pipe a pressurized sample to an analyzer room about 140 ft (275 ft total sample run) from the base of the column. At the time of the installation the dynamics of the process and control systems had not been investigated, but previous experience had indicated the necessity of keeping the sampling dead time or sample transportation lag at a minimum to assure process controllability. Here, the dead time was kept small by withdrawing a main sample stream of about 0.5 gpm—which means a high velocity—from the column and taking from it (in the analyzer room) a side stream of 10 to 20 cc per min.

As indicated in Figure 1, the main sample stream

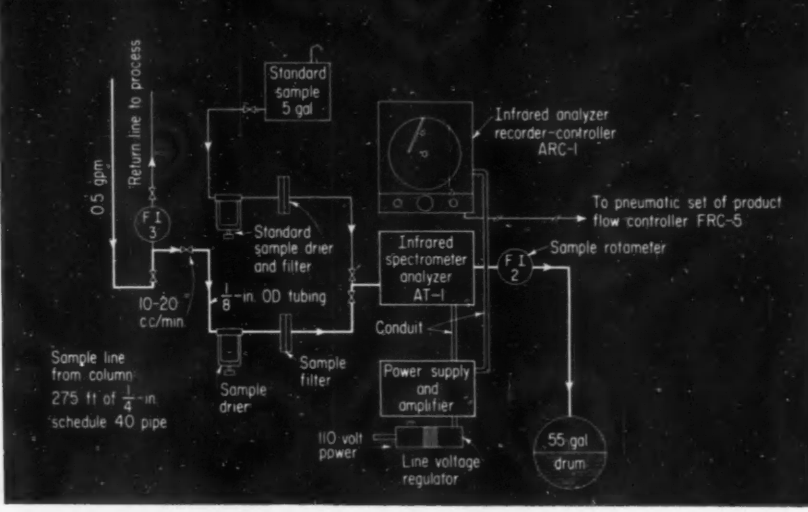


Fig. 2. The details of the sampling system. The heavy line represents the flow of sample liquid from the column at 0.5 gpm, and then through the drier, filter, analyzer, flow indicator, and into the storage drum at 10 to 20 cc per min.

is returned to the process, at the suction side of the overhead product pump. Figure 2 shows the details for the drying and filtering of the smaller analyzer sample before it enters the infrared spectrometer housing; from there the sample is piped through a small rotameter *FI*-2 and discharged into a vented storage drum. This small side stream is not returned to the process, but finds other uses in the plant operation.

The infrared spectrometer *AT*-1 feeds a concentration signal to the analyzer recorder-controller *ARC*-1 which contains proportional, reset, and rate action control functions. The resulting pneumatic output of this controller adjusts the pneumatic setpoint of the associated product flow controller *FRC*-5, which contains proportional and reset actions. There is an integral by-pass arrangement around the analyzer-controller but not around the flow controller.

On-stream results

The infrared spectrometer analyzer *AT*-1 and the recorder-controller *ARC*-1 have been on-stream for about four years and have given better than 98 percent reliability. The major factors in this high degree of reliability are cell design, sample cleanliness, rugged analyzer design, and the protective housing. Accuracy of the reading is assured within one-tenth percent *ortho* by introducing a standard sample at weekly intervals and then correcting for drifts.

Maintenance of the spectrometer and signal amplifier is done by the Spectroscopy Laboratory. Routine maintenance of the analyzer-recorder and the weekly standardization is done by an Instrument Dept. route man, and takes about one-half hour per week. The infrared source has required one replacement in the past four years. The sample cell, using rock salt windows, has also been replaced just once, and then only because the accumulation of polymer on the windows during a plant shutdown altered the cell's transmission characteristics.

Figure 3 shows an actual plant record of concentration control for the 24-hour period of Aug. 28, 1957. The scale calibration of the analyzer recorder-controller is nonlinear and the chart reading is rather arbitrary. The actual value of concentration controlled by the system is company-restricted information. The sudden change in concentration reading occurred during the analyzer's weekly standardization.

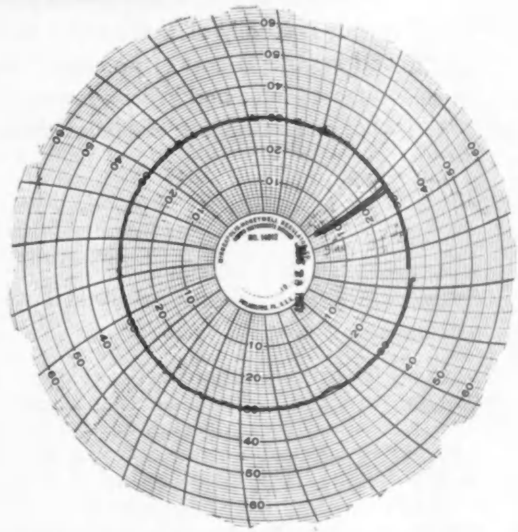


FIG. 3. An actual 24-hour chart record shows how well the analyzer-controller maintains the ortho-isomer at its desired concentration. The calibration is arbitrary.

The present-day cost of building this analyzer-controller is about $5,000, not including the costs of installation of sampling system. Since the original installation four years ago, five similar units have been built for process use. None of these is on closed-loop control because the applications do not call for such operation. It is anticipated that an increasing number of infrared spectrometer analyzers will be used by Dow for stream analysis and control.

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2. *INFRARED ANALYSIS OF LIQUIDS*, L. W. Herscher, "Petroleum Processing", May 1954, pp. 740-746.

How Precise Are Inertial Components?

THE GIST: Inertial navigation—a highly specialized form of dead-reckoning—depends upon sensing and integrating changes in vehicle motion to compute velocity, the first time integral of acceleration, and distance, the second. Successful navigation depends strictly on instruments that mechanize the laws of motion with extreme accuracy. A fraction of a dyne-cm of stray torque is usually all that can be tolerated in a gyroscope or accelerometer, and there is a host of potential "claimants" for their share of this torque. Authors Slater and Wilcox review the many sources of error and point out what can be done to minimize them.

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An inertial navigator determines velocity and position by sensing and integrating craft acceleration. The acceleration-sensing devices mechanize Newton's second law (force equals time rate of change of momentum). The force required to restrain a small known "proof mass", mounted to move freely relative to a base, is a measure of acceleration, in accordance with the familiar expression $F = MA$. To maintain a predetermined orientation independent of craft maneuvers, the acceleration-sensing devices are mounted on a platform stabilized by gyroscopes. The orientation is typically (though not necessarily) level and NSEW. The gyroscopes also mechanize Newton's law in the form $L = \omega H$, where L is torque, ω is angular velocity of precession, and H is gyroscope angular momentum.

Inertial navigation offers vast potential advantages, since Newton's laws hold exactly at any practical speed. Not only are inertial systems completely independent of any input except acceleration, but they can yield a variety of information (besides position coordinates) necessary for craft guidance, and promise virtually unlimited potential accuracy.

The problem is that navigational accuracy depends directly on how faithfully the accelerometers and gyroscopes mechanize the laws of motion. Practical inertial navigation is, therefore, primarily a problem of precision instrumentation. Every conceivable source of error, no matter how small, must be located and eliminated.

WHAT KINDS OF ERRORS ARE ENCOUNTERED?

Errors appear as spurious components of the quantity being sensed—a false acceleration A' and a gyro drift rate ω'. They have three sources:

1. Stray torques or forces acting about or along the critical axis of the instrument.
2. Nonlinear instrument output.
3. Misalignments within the instrument. Gyroscopes and accelerometers must solve vector equations in which direction is as important as magnitude. Errors from the preceding sources may be negligible, yet an instrument may not operate properly because of cross-coupling and other effects associated with improper internal alignment within the component.

Figure 1 shows the navigational position errors resulting from a constant acceleration bias and a constant drift rate referred to a horizontal axis. The stable element is assumed to be initially level. In each case, the oscillation superimposed on the linear component is caused by the Schuler tuning of the system, as explained in the references listed at the end of the article.

Gyroscopes and accelerometers (generically inertial components) have much in common. In each type of component there is an element—translatory or rotary—characterized by mass or inertia that furnishes the M in Newton's second law. This element is supported on bearings of one or more degrees of

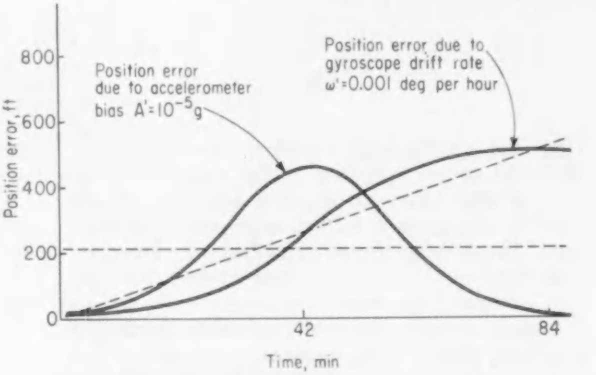


FIG. 1. Propagation of position errors from accelerometer bias and from constant leveling-gyroscope drift rate, assuming platform to be initially level and bias appearance subsequent to leveling.

freedom and designed for minimum stray torque L' or force F'. A position pickoff detects deflections or displacements of the mass about or along the bearing, and usually a predetermined or command L or F is applied to the mass by a torque or force generator. Because of the basic similarities of mechanization, the previously listed sources of error can be examined simultaneously for both types of components. Specific comments will be made wherever they are necessary for clarity.

STRAY TORQUES AND FORCES

These usually constitute the most serious source of error; in inertial components of practical size the permissible stray torque or force is extremely small. Assuming that the permissible constant accelerometer bias is 10^{-5} g's, as indicated in Figure 1, then the allowable stray force F' per gram of accelerometer proof mass is only 0.01 dynes. And if the permissible gyro drift rate is 0.001 deg per hour, then the allowable stray torque L' on the gyro is only 0.005 dyne-cm for each 10^6 cgs units of angular momentum. To get a feel for the magnitude of 0.01 dyne, hold out your hand and try to "weigh" the sunshine. The force due to solar radiation pressure is about 0.01 dyne.

Figure 2 summarizes the forces and torques that act on an inertial navigator stable element. It is the potential disturbing torques that are of concern here. Note that these are divided into acceleration-dependent and acceleration-independent groups. The following discussion deals only with torques, rather than with both torques and forces. This is reasonable since gyros are always rotary, and more often than not accelerometers are too.

Acceleration-independent torques

This group includes frictional, resilient, or magnetic coercion from pickoffs and other transducers, electrical lead-ins, and other fittings and accessories. Interaction between parts of a gyro or accelerometer and the earth's magnetic field, or other stray fields, is also acceleration-independent.

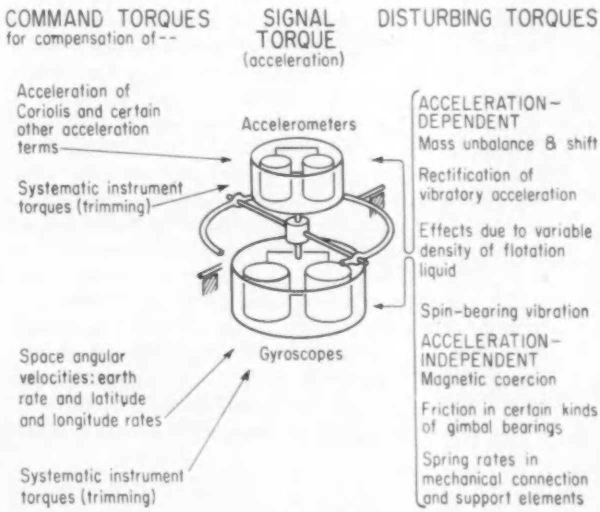
Many of the acceleration-independent sources of error will yield to obvious lines of attack. Sources of frictional torque, such as potentiometers and slip rings, must be avoided. Pickoffs or torque generators that create variable or uncontrolled magnetic effects can cause error torques or moments on the sensitive element. Moving-coil transducers are often preferred to moving-iron transducers, even though they require lead-in wires to the moving element.

In the past the gimbal or pendulum bearing was the main source of disturbing torque, since it had to satisfy a combination of incompatible requirements: low coercion of any sort and particularly zero coulomb friction, adequate load-carrying capacity to withstand the moments associated with gyroscopic precession or with pendulum operation, and accurate and rigid axes to avoid cross-coupling.

Even under unaccelerated conditions, ball bearings have friction-torque levels that are one or more orders of magnitude higher than can be tolerated at the critical gimbal axis of a navigational gyroscope or accelerometer. The principal source of ball-bearing torque is the internal hysteresis of the bearing parts, resulting from preloading (and hence distortion) for proper rolling action and accurate axis definition. Thus friction is still present even though the weight carried by the bearings is reduced to zero by complete flotation of the supported member. Ball retainers also contribute friction. The measured stiction torque of gimbal-type ball bearings capable of supporting loads of about 1 kg ranges from 10 to 100 dyne-cm under ideal conditions.

Supporting the sensitive element (in a gyro: rotor, spin bearing, motor, and gimbal bearing) by gas or liquid has proved effective in minimizing output-axis torque. Properly designed hydrodynamic (pressure-supplied) gas or liquid bearings have negligible

FIG. 2. THESE TORQUES MUST BE STUDIED



static friction. Typically, a hydrodynamic liquid bearing capable of supporting a few hundred grams will exhibit a very small, and strictly systematic, torque. The true random or error torque is so small (a small fraction of 1 dyne-cm) that it is difficult to measure, being obscured by larger error torques from other sources.

A properly designed hydrodynamic bearing also has very low resilient (spring-rate) coercion, is insensitive to changes in load magnitude and direction, and will rigidly define an axis. Stiffness to moments is high: about 10^4 dyne-cm per microradian is typical.

In the best components, the total of the acceleration-independent torques has been reduced so that it does not set the level of instrument performance.

Acceleration-dependent torques

Acceleration-dependent torques constitute a more troublesome class. They are difficult to minimize since the masses involved are so large that even a tiny moment arm can cause an intolerable error. A 100-gm mass on a moment arm of 10^{-7} cm gives rise to a torque of 0.01 dyne-cm at 1 g. Yet 10^{-7} cm is only 10 Angstrom units (the wavelength of visible light is 4,000-7,000 Angstrom units).

The problem is aggravated by the difficulty of detecting acceleration-dependent torques. Gyroscopes, for example, must be subjected to sustained and vibratory accelerations along various axes, while accurately keeping their input axes in a fixed relation to the earth's axis (to avoid spurious drift rates caused by picking up variable components of the earth's angular velocity). The centrifuge, a convenient device for producing multi-g acceleration along a rotating axis, is not totally satisfactory for testing gyros. The smallest misalignment will permit some component of the relatively enormous centrifuge spin velocity to appear as a spurious drift at the gyroscope reference axis.

The most obvious source of acceleration-dependent torque is mass unbalance due to permanent displacement of the sensitive-element mass center from the output axis. The accuracy of this balance depends mainly on the quality of the output-axis bearing and the rigidity of the structure. Proper manufacturing procedures will yield a very low residual mass unbalance that is remarkably stable considering the number of parts and diversity of materials that go to make up a gyro. Strict tolerances mean that not only material creep and joint slippage are important, but also differential thermal expansion across critical parts, and even the weight of minute foreign particles inside the supported element.

A well-designed gyro is rigidly constructed of stable materials. At present, alloyed aluminum, for example stabilized 2024, is the most-used metal. Beryllium has recently found favor because of its low specific gravity (approximately 1.8) and because its thermal expansion coefficient is close to that of the iron and steel used in the motors and ball bearings. The rigidity requirement applies to the pickoffs and torquers as well as to the structure of the rotor, gimbal, and output axis bearing. Where possible, one-piece construction is used. A high degree of symmetry about the output axis minimizes mass shift, not only from creep or shift, but also from thermal differences.

A more insidious source of acceleration-dependent disturbing torque is the unequal compliance of the sensitive element when accelerated in different directions. This is known as "anisoelasticity".

Consider a gyroscope rotor mounted in ordinary radial ball bearings which have substantially greater compliance in thrust (along the spin axis) than radially. These bearings might be thought of as a diaphragm-like spring which supports the rotor mass relative to the gimbal, Figure 3. Acceleration along any of the principal axes causes no moment, but acceleration A along an intermediate axis will cause a moment MAr which, if the compliance is linear, varies as the product of the acceleration components along the two axes. Furthermore, the moment does not change sign if the acceleration reverses; vibratory acceleration causes a rectified torque, hence a net drift rate. Since the effect varies as g-squared, it can be serious in multi-g environments.

Since it is impossible to achieve absolute rigidity, the approach has been to design the bearings and other critical parts of the structure so that compliance is equal in all directions. Then the inevitable mass deflection takes place in the same direction as the acceleration and no moment is produced. This construction is "isoelastic".

For ball bearings isoelasticity can be achieved by maintaining a predetermined bearing contact angle—typically 35 deg, but depending to some extent on the type of bearing and its support. Gyro ball bearing assembly is very critical. Not only is there a tight tolerance on the contact angle (which is a function of preload), but the likelihood of mass shift on change in temperature makes it impractical to fix one end of a gyroscope rotor shaft and let the other end float. Ordinarily the angular-contact bearings are installed as one, or two, closely spaced pairs preloaded against each other.

Ball bearings yield still another source of disturbing torque which, while not acceleration-dependent itself, can give rise to effects that are acceleration-dependent. This source is the mechanical noise (vibration) generated by the bearings in those instruments that use ball-bearing mounted rotors (gyroscopes and certain integrating accelerometers). This noise aggravates any tendency of the rotor or other parts of the structure to creep or displace. The gas-lubricated spin bearing, virtually vibration free, will remove this troublesome disturbance.

In pendulum-type accelerometers—as distinguished from the true translational (slide-bearing) type—vibration resulting from torsional compliance of the acceleration-sensing element or servo can cause a

rectification error torque effect analogous to that of anisoelasticity. Again this torque is caused by the center of mass of the pendulum not moving along the same line as the applied acceleration.

Consider a vibratory acceleration A applied at an angle θ to the sensing axis of the instrument, Figure 4. The compliance K of the servo restoring loop for the pendulum will allow the pendulum to deflect through some small angle α, and a rectified error torque will result that is a maximum when the vibration is applied at 45 deg to the sensing axis. This torque can be minimized by minimizing the effective torsional or servo compliance K at the predominant frequency (tightening the servo loop).

The last class of acceleration-dependent torques is associated with the liquid flotation medium in "wet-type" instruments. All ordinary nonaqueous flotation liquids have substantial thermal volumetric coefficients of expansion of about one part in 1,000 per deg C. This causes two types of errors:

1. If a temperature differential exists across the floated gimbal, the liquid on the hot side will move away from the direction of applied acceleration and the resulting circulation will exert a drag torque on the float. In typical inertial gyroscopes a torque of several dyne-cm at one g for a differential of 1 deg C can be expected. Thus there is a critical problem of equalizing temperatures across the instrument, especially in multi-g acceleration.

2. If the center of buoyancy of the float does not lie on the axis of support, a change in liquid temperature will produce a moment. Assume, for example, a one-liter float, formed as a cylinder, sphere, or other true figure of revolution, the center of which lies 10^{-3} cm off the axis of support (gimbal axis). If the liquid specific gravity is unity and its thermal volumetric coefficient of expansion one part in 1,000 per deg C, a change of one deg C results in a one dyne-cm moment at one g. This problem is so critical that even for one-g applications the float must be generated as an absolutely true figure of revolution about the support axis.

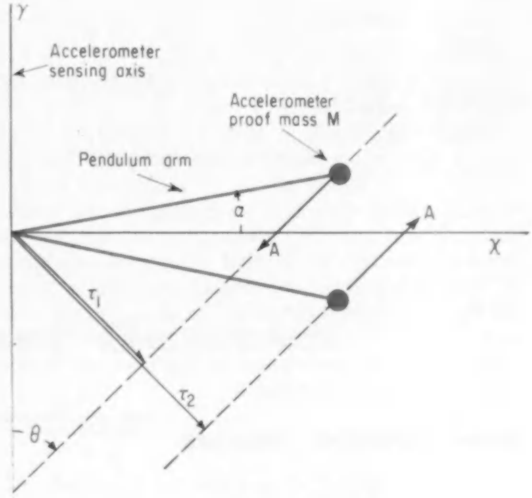


FIG. 4. Rectification torque on an imperfectly constrained pendulum.

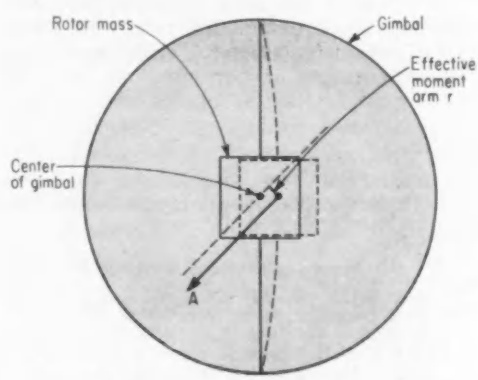


FIG. 3. Representative anisoelastic structure.

SCALE FACTOR ERRORS

A gyroscope must often be precessed in space at some predetermined rate; for example, at latitude rate $\dot{\lambda}$ to keep the gyro level when the craft changes latitude. To do this a control torque $L = \dot{\lambda}H$ must be applied. Angular momentum H is held to a constant average value by using a synchronous drive motor, powered by a source referenced to the time integral of frequency. Short-period speed deviations from motor hunting and other sources are ordinarily not important. Torque L is generated by a simple and accurate transducer consisting of a coil on the gimbal extending into the gap of a magnet on the case. Torque linearity vs. applied current can be held to better than one part in 10,000.

Before considering accelerometer scale factor errors, note that an inertial navigator accelerometer is usually required to give an output proportional to the first or second time integral of acceleration, rather than to acceleration directly. Thus linearity of the integral term is the important point, and integrating accelerometers must be discussed.

Nonintegrating accelerometers can be used, in conjunction with separate integrators. However, there is a gain in overall simplicity and reliability if the functions of sensing and integrating are combined, at least one stage of integration being carried out directly by the instrument itself. Accordingly, so-called integrating accelerometers must be considered in inertial systems.

Various ingenious integrating accelerometers have been developed. Military security regulations limit the discussion to the inertia-rotor double-integrating accelerometer and the gyro-pendulum single-integrat-

ing accelerometer. Both integrate by mechanizing Newton's second law.

In the double-integrating type a servomotor-driven inertia rotor is contained *within* the pendulous element. When subjected to a translational acceleration, a pickoff detects the deflection of the pendulous element and the servomotor is energized to develop a reaction torque that restores the pendulum to null. Thus the translational acceleration acting on the pendulum is converted to an angular acceleration of the rotor. Rotor velocity and rotor displacement angle are proportional to the first and second time integrals of acceleration.

The single-integrating accelerometer—such as was used in the German V-2 missiles and is used today in a refined form in certain U.S. missiles—involves a small single-axis gyroscope in a rotatable gimbal. The gyroscope is unbalanced so that a torque and subsequent precession velocity are generated when it is subjected to a translational acceleration. Thus the angle through which the gimbal rotates is proportional to the first time integral of acceleration.

Both devices are inherently linear, being direct mechanizations of Newton's second law. The potential sources of error are those described for gyroscopes and accelerometers.

MISALIGNMENT ERRORS

In accelerometers using a pivoted pendulous element, a departure from null by an angle α permits cross-coupling of acceleration A along a transverse axis (X-axis in Figure 4) equal to an amount $A\alpha$. This is quite independent of the torque-rectification effect described above, which is also a function of α. Cross-coupling can be a serious source of error in systems used in high-performance aircraft that are subjected to large acceleration components along all axes. A tight servo loop is the best cure.

Somewhat analogous cross-coupling effects can take place in a set of gyroscopes when command torques are applied to cause predetermined *variable* space angular velocities—for example, earth rate components and latitude and longitude rates. These effects cannot be made completely clear without presenting an extensive analysis, but briefly, unless the input (or equivalent reference) axes of a set of gyroscopes are accurately orthogonal (or at some known deviation from orthogonality), applied command torques will cause gyroscope precession components about unintended axes, with a net result that is exactly equivalent to drift rates produced by stray torques.

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CONTROL ENGINEERING
18
DATA FILE

Protection of Sensitive Current Devices with Silicon Diodes

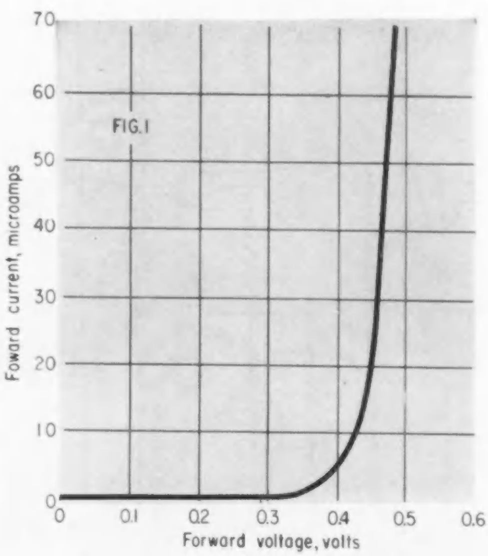
PERRY L. TOBACK, Hoffman Electronics Corp., Semiconductor Div.*

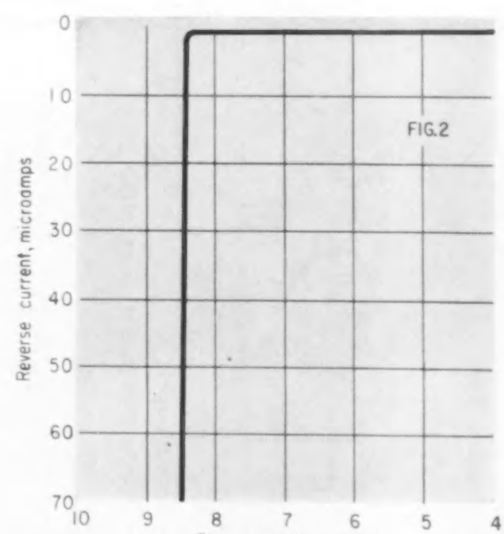
Highly sensitive current devices such as meters and relays are basic components of virtually all control systems. But current and voltage surges may severely damage these devices, and it is necessary to find some way to protect them. The forward characteristics of silicon diodes and the reverse characteristics of silicon zener diodes make these diodes suitable for the job. Properly used in simple circuits, they maintain instantaneous and continuous protection. This data file shows the circuits and details the degree of protection they offer.

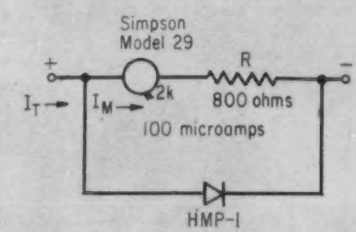
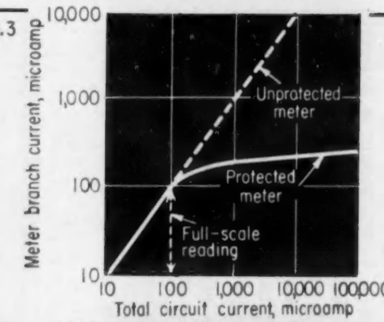
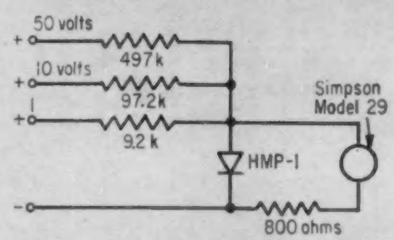
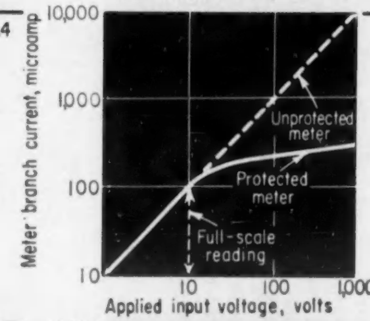
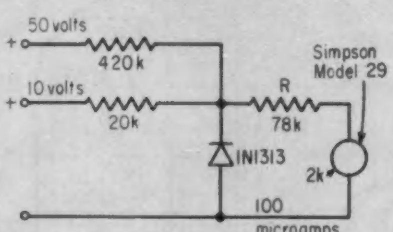
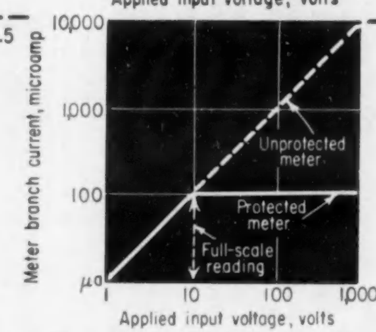
Figure 1 shows a typical volt-ampere characteristic for a forward-biased type HMP-1 silicon diode. The curve indicates that below 0.30 volt the forward current of the diode is in the order of tenths of a microamp. Below 0.30 volt, its shunting effect on a meter having a full-scale deflection of 100 microamp is in the order of tenths of a percent, much less than the inherent error in the meter itself.

Figure 2 is a typical volt-ampere characteristic curve for a reverse-biased 1N1313 (ZA8) silicon diode. This graph shows that the zener characteristic can also be effectively utilized for protective shunting.

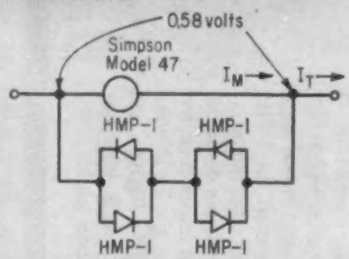
*Currently employed at Radiation Counter Laboratory

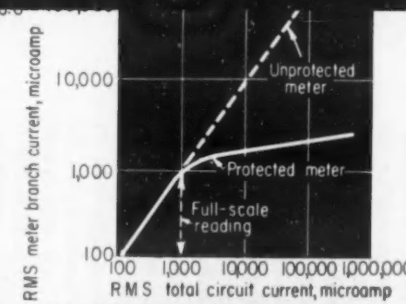




PROTECTED DEVICE AND CIRCUIT	PROTECTION CHARACTERISTICS	APPLICATION REMARKS	DEGREE OF PROTECTION
DC MICROAMMETER 	FIG.3 	Because the Simpson Model 29 used has a resistance of 2,000 ohms and a full-scale current of 100 microamp, *R* was made equal to 800 ohms to develop a maximum of 0.28 volt across the diode. *R* is low enough to prevent shunting of the meter by the diode until current reaches full scale. A larger value of *R* will increase the protection, but at the expense of a slight nonlinearity near full scale.	The protection curve shows that for a total circuit current of 500 milliamp (the maximum rated forward current for the HMP-1 diode), the meter is subjected to a current only slightly in excess of 300 microamp. When 5,000 times the rated meter current flows in the circuit, the meter "sees" only three times its rated value.
DC VOLTMETER **1. Using diode forward characteristics** 	FIG.4 	A 100-microamp dc meter protected by a forward-biased silicon diode can be converted to a 10,000 ohm-per-volt voltmeter by the addition of multiplying resistors (shown).	The plot of meter branch current as a function of input voltage applied at the 10-volt tap indicates that for an input voltage 40 times rated value the meter is subjected to only 2.5 times its rated current.
2. Using diode reverse characteristics 	FIG.5 	*R* was chosen as 75 k, producing 8.0 volts across the Zener at full meter current. Comparison of Figures 5 and 3 demonstrates the greater effectiveness of Zener (reverse-biased) protection. However, forward-bias protection performs better at the lower voltages.	When 400 volts is applied at the 10-volt tap, the meter sees only 110 microamp, or, for a voltage input 40 times rated, the meter is subjected to only 10 percent overload.
		MICROWATT RELAYS AND LOW-CURRENT METER-TYPE RELAYS The protective characteristics obtained with diodes on meters may be obtained on dc microwatt relays as well. With meters it is of prime importance to protect the d'Arsonval movement and pointer from damage due to overload. With microwatt relays, one protects against core saturation because it causes nonrepeatability.	

AC MILLIAMETER





The forward characteristics of silicon diodes may be used to protect ac milliammeters such as the Simpson Model 47. This meter has a 1-milliamp rating at 0.58 voltage drop. Because of the large voltage drop, two pairs of parallel-connected diodes are used in series.

For a current 500 times greater than the rating of the meter, the meter is subjected to only 2.5 times its rated value.

AC VOLTMETER

1. Using diode forward characteristics

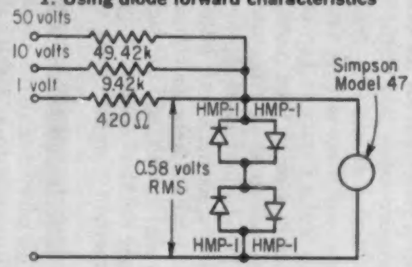
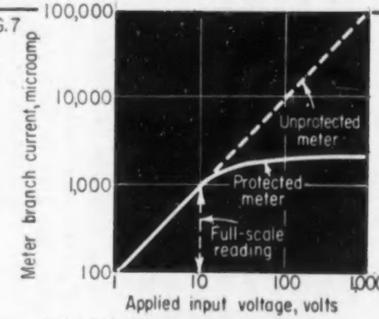


FIG. 7



The ac ammeter protected by two pairs of diodes (described immediately above) can be converted to an ac voltmeter by multiplying resistors. The circuit to the far left shows the result.

The protection characteristic curve indicates that when 40 times rated input voltage is applied at the 10-volt tap, the meter is subjected to only 2.0 times its rated current.

2. Using diode Zener characteristics

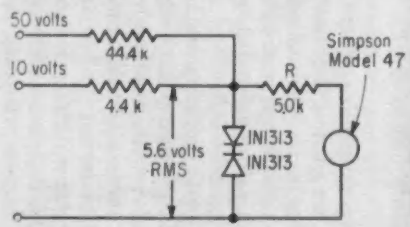
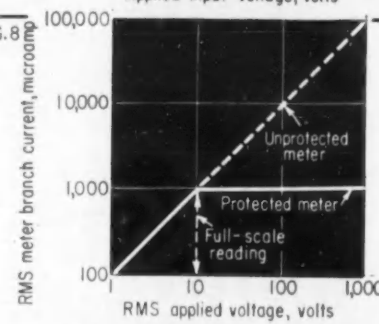


FIG. 8



The circuit to the far left illustrates the use of the Zener (reverse-biased) characteristics of two 1N1313 (ZA8) diodes to protect an ac voltmeter.

For a voltage of 50 times rated voltage applied at the 10-volt tap the meter is subjected to only 5 percent more than its rated current.

3. Using double-anode diodes

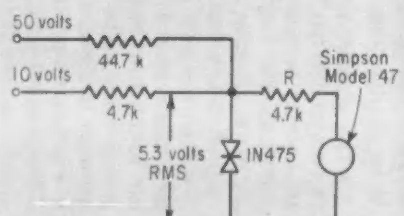
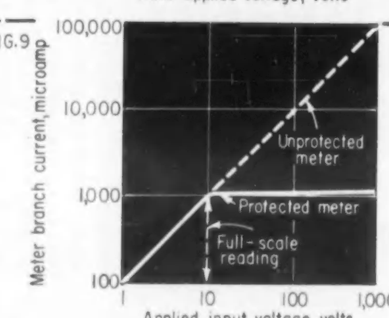


FIG. 9



Double-anode silicon junction diodes can protect an ac voltmeter as well as a pair of single-anode Zener diodes. The circuit at the far left demonstrates the use of a 1N475 double-anode silicon junction diode for this application.

For 40 times the rated input voltage (applied at the 10-volt tap) the meter is subjected to only 10 percent more than its rated current. Comparison of Figure 7 with Figures 8 and 9 demonstrates again the increased effectiveness of Zener protection.

What About Digital Transducers?

Here are the answers to some what's and why's about an important new trend in measurement techniques. The intention here is not to compare practical or available "digital transducers" on a physical basis, or even by input and output specifications, but rather to consider the functional requirements underlying all of them, and also to engender a more fundamental understanding of the advantages that can be gained from the use of digital transducers, as well as the problems and limitations that can be encountered. The article covers:

- ***What a digital transducer is***
- ***Why use digital transducers***
- ***How to specify them***
- ***How to compare them***

E. J. KOMPASS, Control Engineering

A transducer, in its broadest sense, is any device which can couple unlike systems, transferring energy from one to the next and converting units. But it is generally more useful for the control engineer to consider that it transmits *information*, regardless of energy level. A digital transducer, then, is any coupling device that passes data along in some form of discrete code to some unlike system or subsystem. Note that this definition says nothing about the complexity of the transducer or the form of its input.

The natural question is, "Why use a digital transducer at all?" Why digitize a signal when it very likely represents some physical dimension or state that exists continuously in time or space? There are several good reasons, and they have evoked the growing interest in digital transducers that prompted this article.

Why digitize data?

• The most important reason for digitizing data is that digital data can be stored for any length of time, transmitted over any distance and re-transmitted, and detected or read as many times as necessary with no loss in accuracy. Analog signals are distorted by each of these processes, and accuracy is lost.

• Another reason is that certain digital yardsticks are available by which time and distance and velocity can be measured to much higher accuracies than by analog means. The use of these yardsticks leads naturally to digital sensing transducers.

• A third reason often stated is that the output of a digital transducer can be made compatible with the inputs required by digital control computers or data-logging or data-reduction equipment. This reason would make the choice of the type of transducer depend on the previous choice of other equipment.

It follows from the first reason that if data is to be digitized at all, the digitizing should be done as near as possible to the point of measurement—within the primary sensing transducer itself, if possible.

Appreciation of the performance gains potential in digital systems must lead to the development and commercial availability of digital sensing transducers for every kind of measurement. Beginnings of this appreciation are now evident, but usually only in relatively complicated, expensive systems which can stand the development costs of tailoring available digital devices to fit into systems which still are, on the whole, conventionally analog. Continuous, real-time digitizing of control system signals is applied most easily today where maximum signal frequencies are low—in the order of cycles per minute or a few cycles per second. This is because equipment for sampling and digitizing at high rates is still costly and very complex. Certain important control system functions, on the other hand, are performed more accurately and at the same time more simply by digital devices—for example, the simulation of pure dead times of long duration. Digital techniques also make it easy to generate the intentional nonlinearities being used more and more to get better response from servomechanisms and controllers.

Standardization of the forms of outputs of digital transducers must wait until enough experience has been gained from widespread use of the early commercial models, and this lack of standardization will make the third reason for digitizing stated above less important than the others, at least for a while.

Pulses are not always digital

To partake of all the advantages cited above, a signal must be truly digital. For example, whether or not a transducer which produces a train of pulses is

truly digital depends on its application. A toothed wheel on a shaft can produce pulses from a contact or magnetic pickup that represent discrete increments of shaft revolution, see Figure 1. But the output of the pickup is not digital if the device is used to measure shaft speed, i.e., as a tachometer. The output is in pulse form, all right, but the measured variable is represented by the *frequency* of the pulses, and frequency is an analog quantity.

As a position sensor or revolutions counter, however, the toothed wheel is truly digital. The position of the shaft or number of revolutions (measured to the fraction of a revolution represented by the number of teeth on the wheel) is determined by the *number* of pulses past some reference point. This signal can be distorted only by completely missing one or more pulses. Subtle distortions are not possible.

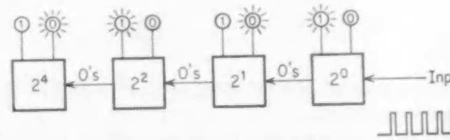
This brings us to an appreciation of pulse-type (on-off, two-state, binary) signal transmission techniques in general. Such signals exhibit a radical improvement in detectability in the presence of wide-band noise of Gaussian amplitude distribution when the signal power reaches 20 db over the average noise power in the band (Ref. 1). For very small increases in power above this 20-db level, loss of a pulse or false detection of noise as a pulse becomes extremely unlikely, see Figure 2. With careful circuit design, pulse detection can be made more reliable than the equipment itself, so that when a pulse is finally missed, it will be due to a component failure and not to the signal-to-noise characteristics of detection.

Transducers which produce a series of pulses like the toothed wheel require a counter of some kind to accumulate their outputs. As a tachometer, the output pulses must be counted over a precise time interval; then, the whole combination of counter, time-base generator, and toothed wheel may be considered a digital transducer of shaft speed.

Counting can be done by two-state elements such as relays or magnetic cores, by storing each succeeding pulse in a separate element, in which case the position of the last element represents the final tally. But this is wasteful of equipment even for small numbers, and is impractical for large numbers. Thus, counters usually interconnect binary elements to produce some coding of the number which is the output (Ref. 2), see Figures 3 and 4. There are other reasons for coding digital signals besides equipment economy, however.

Reasons for coding

All pulsed-data transmission systems trade time for bandwidth, and signal-to-noise ratio is intimately associated with the time-bandwidth product. Previous to coding, data pulses are usually counted in sequence, over an interval that may be defined by bracketing or synchronizing pulses. These bracketing pulses are transmitted also, either in another channel, or in the same channel as the data pulses but distinguishable from them. Although the bracket pulses may be a function of position rather than time, nearly every system puts a maximum limit on the time between bracket pulses. Therefore, to increase the amount (or precision) of data transmitted between bracket pulses, either the time between brackets must be increased, or if this is limited, the bandwidth of the channel must be increased to accommodate a higher pulse rate. As bandwidth (or time) is increased, however, the system is made vulnerable to



Representation of number 25

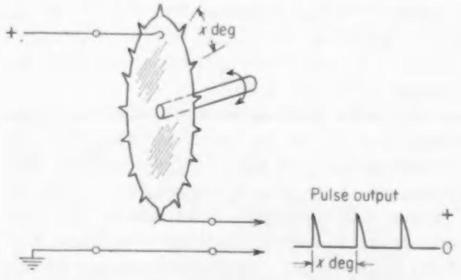
Tally	|||||||||||||||||||||||||				
Decimal	2 (10's)	5 (1's)			
Binary	1 (16's)	1 (8's)	0 (4's)	0 (2's)	1 (1's)
Binary-coded decimal	0010 (2)	0101 (5)			

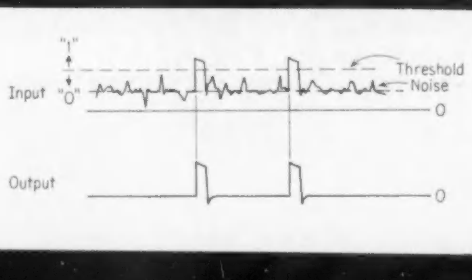
FIG. 3. Simplified representation of a binary counter. Output is in straight binary code. Each succeeding stage is triggered by every other input to the stage before. Counter shown has counted five input pulses.

FIG. 4. Comparison of number systems shows economy of time and space possible by coding. The straight binary code is the most economical code using two-state logic.

FIG. 1. The "toothed wheel" transducer produces an output pulse for each increment of angular position. It is a digital as a position transducer analog as a tachometer.

FIG. 2. "Binary" signals can be made almost completely recoverable if the recognition threshold is more than 20 db above the average noise level.





new sources of disturbance, and the signal-to-noise ratio is reduced.

Coding reduces the time-bandwidth product required to transmit a signal of any given precision, and thereby improves the signal-to-noise ratio. For example, to transmit a signal with a precision of 1 part in 1,000, a pulse count system requires 1,000 pulses per frame (between bracket pulses), while the same signal can be transmitted in straight binary code form by only 10 pulses per frame ($2^{10} = 1{,}024$).

Besides this, coded data can be made even less vulnerable to noise, as well as protected against "drop-out" of data pulses due to dynamic malfunction of equipment (such as holes in magnetic tapes), by the simple addition of a "parity bit". A parity bit is an extra binary digit computed and added at the end of the coded number to make the total number of 1's in each frame always even or always odd.

Pulse count systems are normally serial; i.e., pulses are counted sequentially. Coded digital signals can be either serial or parallel. Serial systems use less transmission equipment, since all data is carried by a single channel, but bandwidth requirements can make the equipment expensive for high information rates. Parallel systems use a separate (narrower-band) channel for each code bit and are more expensive for low information rates. The choice very often depends on the characteristics of associated equipment, however.

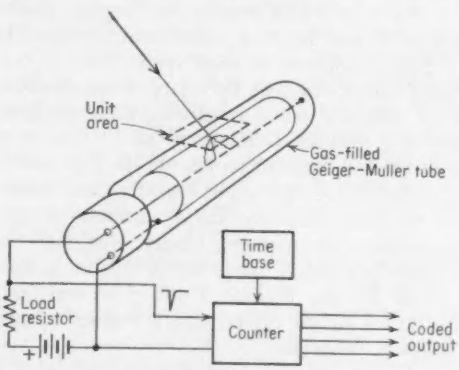


FIG. 5. *Geiger-Muller tube taken with a timed counter can be considered a digital transducer with digital input.*

The nature of input data

It is next necessary to examine the form of the input data before the job of digital transducers is defined. Before the ordinary physical considerations of whether the input data is heat or light or motion is the more basic one of whether the data is continuous (vs. time or any other parameter) or discontinuous; i.e., whether it is analog or digital.

Considering what appears to be the simpler case first, it can be seen that even if the input to a digital transducer is in digital form, some kind of code conversion is still likely to be needed in the transducer. This is because natural inputs, even where they do exist in the form of discrete step changes, are never in binary or binary-coded-decimal form.

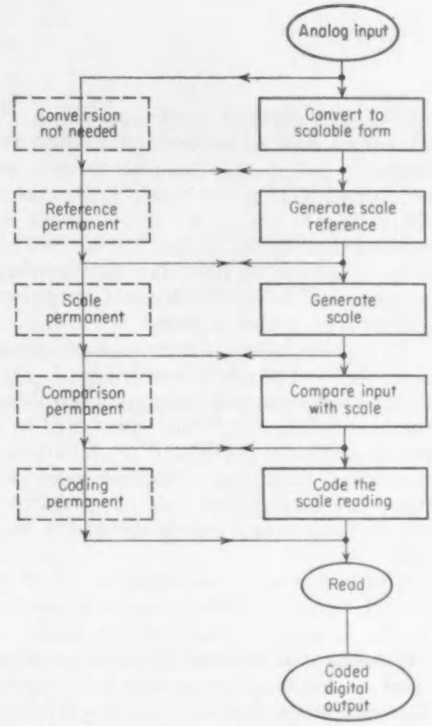


FIG. 6. *Functons which must be performed by analog-to-digital transducers. Note that each function may be done permanently when the transducer is manufactured, or each time it is read out.*

If the data is already digital, of course, use should be made of this fact, and a transduction mechanism used which does nothing but perform the required code translation. For example, nuclear radiation flux density can be measured as the number of particles per second passing through a unit area. Since a Geiger-Muller tube can be made to produce a pulse for each particle passing through it, its output is a digital pulse-count representation of radiation flux density when accumulated over 1 sec, as in Figure 5. Note that the Geiger-Muller tube needs an accumulator to make its output useful just as the toothed-wheel of Figure 1 did.

There has been considerable implication lately that similar use might be made of the basically digital nature of many of the physical variables that are now measured by analog transducers. For example, pressure is rigorously described as the rate of occurrence of collisions between molecules of a material per unit volume. A digital measure of the pressure of a gas should therefore be possible by counting the number of collisions per unit time of the gas molecules with the surface of a transducer immersed in the gas.

In such a transducer, it would be necessary to note

each individual impingement of a gas molecule to maintain the validity of the digital measurement. Quite aside from the difficulties of making a transducer sensitive to such small energies, the technique is made useless by its gross inefficiency. A counter with a greatly excessive number of stages would be necessary. Such precisions, even if possible, are inconsistent with engineering requirements.

There are possibly other variables, however, which exhibit digital characteristics at a more usable level. One is the step-by-step manner by which ferromagnetic materials change their degree of magnetization (the Barkhausen effect). This effect is detectable since it is due to the reorientation by field forces of finite-sized magnetic domains.

In general, it is probable that the digital characteristics of materials due to mechanisms at the molecular or even the granular level of materials will not prove rewarding as a way to simplified transducers with digital output.

Analog-input digital transducers

The majority of "digital transducers" will have analog input to a standard analog transducer, followed by an analog-to-digital converter (Ref. 3) and coder. Presently practical digital transducers are therefore closely linked to the analog-to-digital conversion techniques which are available.

Figure 6 shows the functions which must be performed by an analog-input digital transducer (an analog-to-digital converter may be considered a digital transducer if the variable to be measured is already in the analog form which the converter accepts). Note that it is possible to avoid doing each of these functions every time the transducer is read out, as inferred by the dashed boxes. The only example of complete bypassing of all the functions (except read) is the shaft-position encoder, an example of which is shown in Figure 7.

The shaft position encoder has its digital scale directly attached to the shaft, permanently referenced and encoded. Fixing the position of the readout brushes makes the comparison permanent. It is only necessary to close the brush circuits (this is also done with photocells) to get a coded representation of the analog shaft position (Ref. 3). The shaft-position encoder is thus a very efficient digital transducer.

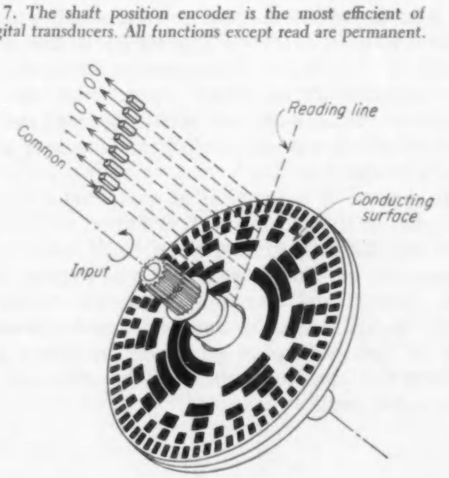
Linear scale transducers are available which have the same basic advantages of the shaft position encoders (Ref. 4). A typical linear position encoder is shown in Figure 8. These devices have been designed to digitize translational motion directly, avoiding the very precise gearing which would be needed to measure linear motion with a shaft position transducer.

Any scale must be referenced to the input each time it is read. This referencing may not be permanent. With the toothed wheel referencing can be reduced to once per revolution if the accumulator contents are not destroyed by readout, i.e., if the counter retains the total count since the last reference no matter how many times it is read out. Note that if the input shaft position can change in either direction, polarity-sensitive logic must determine whether the counter adds or subtracts the input pulses. Logic circuits for polarity or direction sensing are here considered part of scale-referencing.

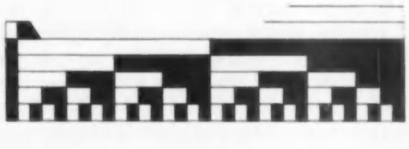
The toothed wheel has a permanent scale, but unlike the disc encoder its scale must be referenced to the shaft by auxiliary equipment. Some digital transducers, on the other hand, must actually generate the scale itself each time the transducer is read. A good example is the comparator type of voltage encoder, which is a digital transducer of voltage.

In Figure 9, a linearly rising voltage of step form is generated by adding up the energies in each succeeding pulse from a master timing oscillator. This staircase voltage is compared to the input voltage to be coded, while a counter counts the pulses produc-

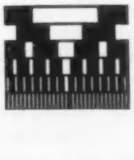
FIG. 7. The shaft position encoder is the most efficient of all digital transducers. All functions except read are permanent.



A



B



C

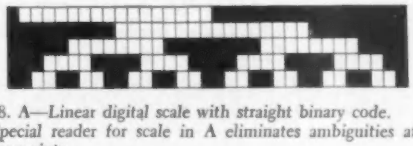


FIG. 8. A—Linear digital scale with straight binary code.
B—Special reader for scale in A eliminates ambiguities at change points.
C—Gray-coded scale can be read with single slit, but presents code translation problems.

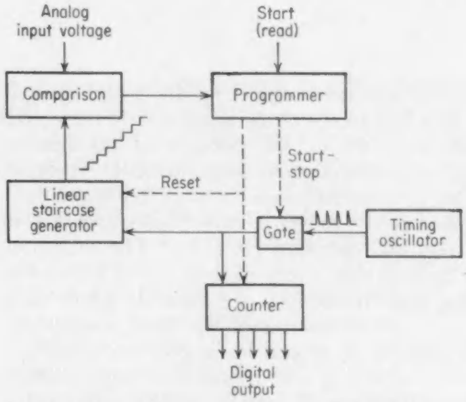


FIG. 9. Voltage comparison encoder of "staircase" type generates digital scale each time it is read.

ing the staircase. At the first pulse for which the staircase voltage exceeds the input, the comparison circuit produces a stop signal and the counter contains a coded-digital representation of the input voltage. The counter and staircase generator must be reset to zero before this circuit can be read again.

Note that this technique effectively converts the voltage input to a time interval, which is then measured by counting the number of pulses (cycles) of the precisely known oscillator frequency which it contains. In spite of the extreme precisions with which pulse frequencies can be generated (crystals are available with resonant frequencies accurate to one part in a billion), this type of converter is limited by the linearity of the staircase generator and the sensitivity of the comparison circuit. Practical accuracies for such converters run up to about 0.1 percent (3 decimal digits or 10 binary places). This seemingly low accuracy is offset by the high sampling rates permissible. Using a 5-megacycle oscillator frequency, the input can be sampled up to 100,000 times per sec with 0.1 percent accuracy.

Other voltage encoders use a fixed digital-to-analog scale such as a series of very accurate voltages in power-of-2 increments that can be added to approximate any analog input voltage. A number in the output counter closes circuits to sum the corresponding digital voltages and this sum is compared with the input. If the output is larger than the input the number in the output counter is reduced one count (or vice versa) and compared again.

A third technique compares the input to the largest voltage source first, and if it is larger than the input, turns it off and tries the second largest. If the largest voltage is smaller than the input, the next larger voltage is added to the first and the sum compared with the input; etc. The result is the correct selection of voltage sources to most nearly match the input voltage, and a reading of voltage sources that are "on" yields the digital code for the input. One part in a thousand decimal accuracy can be had at sampling rates up to 50 kc.

Note that the measurement reference for the two voltage encoders just described is fixed permanently at the signal ground potential, but the digital scale must be generated each time in the case of the "staircase" encoder.

Available analog-to-digital converters measure only mechanical position (mostly angular, some linear), voltage, or frequency (by counting over an accurate time interval), and other input variables must generally be converted to one of these forms. To illustrate how analog transducers can be used with available converters to form rather complex "digital transducers" consider the problem of digitizing a variable pressure.

Small pressures can be digitized by using a servo to position a disc encoder according to the motion of a bellows-actuated differential transformer. Larger pressures might use a bourdon tube to position the encoder disc directly. Another way, found useful over a very wide range of pressures, uses a vibrating wire transducer (in which the pressure changes the tension and hence the natural frequency of the wire) in combination with a frequency counter-encoder. Other oscillators can also be made frequency-sensitive to pressure changes, but the problems are frequency stability and sensitivity to other variables such as temperature.

Limitations on accuracy

The accuracy limitations of all three "digital pressure transducers" just described would be in the order of 0.1 percent of full scale. Disc encoders are available that use multiple discs and gearings to get accurate coding of the input shaft position to one part in 524,288 (2^{19}). But it is impracticable to position the input shaft as a function of another variable to much better than three accurate decimal places, or 0.1 percent.

The multiple-disc encoders are used in reverse; i.e., the measured variable is entered at the high-speed end and the smallest division equated with a fixed maximum allowable error in the measurement. For example, the high-speed end might be geared to the work table of a milling machine such that 0.0001 in. of table motion is equal to the smallest division of the high-speed disc. The table position could then be read to 0.0001 in. plus or minus half a quanta (plus or minus 0.00005 in.) anywhere within a total travel of 52.4288 in. This assumes, of course, that the measurement is always made from the same direction to eliminate backlash in gearing, and that the entire machine is carefully stabilized at a specified temperature.

In general, it is practical to read single-disc shaft encoders to 10 or 11 bits with certainty, and possible, but very difficult, to read them to 13 bits. These limitations are due to play and eccentricity in the disc bearings and to nulling errors due to friction if the disc is servoed to another variable, as well as due to the mechanical or optical problems of resolving the tiny code zones if the discs are kept reasonably small.

Frequency (hence, time) can be encoded with very great accuracy, but any transducer which produces a frequency proportional to another variable limits the accuracy of measurement of that variable by its own nonlinearity.

The maximum sampling frequency is another important characteristic of the digital transducer. The frequency at which disc encoders can be read varies considerably, depending on their design. Some disc encoders, for example, use a code which can give ambiguous readings at the code boundaries, or which could be damaged by reading while the disc is moving, and these generally require that the disc be stopped in a detent before it can be read. Such encoders are limited to 10 readings per sec.

Other (mechanical readout) encoders remove the brushes from continuous contact with the disc between readings to reduce friction and improve the accuracy of positioning, and these then require that the brushes be moved into contact with the disc at each reading. Such designs may raise the limit to 20 samples per sec or more.

When the brushes are in continuous contact with the disc, or when photo-cells are used to read an optically-coded disc, the reading speeds are limited only by electronic circuitry. In such cases, the speed at which samples should be taken depends on the system in which the encoder is used.

Sampling theory states that, to reproduce exactly a varying input signal, the signal must be sampled at a frequency that is at least twice that of the highest frequency present in the input to the sampler (encoder in this case). Note that it does *not* say twice the highest frequency of *interest* in the input, but twice the highest frequency *present* in the input. If the higher input frequencies are not significant, or if available encoders cannot sample fast enough for the higher input frequencies, they must be removed by filtering prior to sampling; else the output signal may be incorrect. Note that the high-frequency response characteristics of a servo which positions a disc may act to filter higher frequencies present at the servo input. Sampling theory has been discussed in considerable detail by D. T. Ross of MIT (Ref. 5). In reproducing the signal from the samples, the difficulties of designing low-pass filters good enough to sufficiently attenuate the sampling frequency without reducing the amplitude of the higher frequency components of the signal generally require that *practical sampling frequencies* be five to ten times the highest frequency present in the signal.

Comparing digital transducers

Once it is decided that its basic advantage of complete preservation of measurement precision in all subsequent signal handling justifies using a digital transducer in a particular application, the next problem is selecting the best one for the job. The basic requirements for selecting any kind of transducer apply here, too. The transducer must:

- Accept the input to be measured, and
- Produce an output of the proper form (in this case, in the desired code). Further, its output must:
- Be accurate enough (have a sufficient number of *realistic* code bits), and
- Be available as often as needed; i.e., the maximum sampling rate must be high enough.

These last two requirements involve the errors due to quantization and sampling.

Once the field of available digital transducers (including analog transducer-converter combinations) has been reduced to the few that are usable from these considerations they can be compared to Figure 6 to determine their relative efficiency of operation. The transducer with the least number of active functions can be considered the best of those that satisfy all the other requirements, since each active function must add inaccuracy and reduce reliability. The amount by which each function affects accuracy and reliability varies greatly with the manner in which the function is performed.

The most important reason for using the digital transducer is the relative immunity of digital signals to distortion by noise and nonlinearities, and this applies inside the transducer, too. When not permanent, the conversion, referencing, and comparison functions in Figure 6 are basically analog, and the scale generating and coding functions are pulse-count digital. Under the usual conditions, 10-bit coded digital signals (0.1 percent accurate) are over 20 db less susceptible to "noise" than are pulse-count digital signals, and 60-70 db better than analog signals. And, in a coded system, signal-to-noise ratio improves as code bits are added to increase precision.

The conversion, referencing, and comparison functions thus would possibly increase the susceptibility of the transducer to distortion by noise by a factor of 1,000 each; and the scale generation and coding functions by 10 each. Actually, these factors can be effectively negated by providing sufficient signal power at each active stage to override circuit noise. But it is well to keep in mind the price that must be paid when digital techniques are not used—inside the transducer and inside the system.

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Chemical Kinetics and the Dynamics of Chemical Reactors

Automatic control of chemical reactors is probably the most critical control problem facing the chemical industry today. And it is a major one also for the petrochemical and petroleum industries. Investigation programs now under way in several companies are pointing up two important facts: reactor control must be analyzed theoretically, not experimentally, and the resulting complicated equations have to be solved on a computer.

The author relates chemical kinetics and reactor dynamics to automatic control by describing:

- **fundamentals governing a chemical reaction,**
- **common reaction vessels and their dynamics, and**
- **ways to achieve the best combination of reactor and control system, and best ultimate yield from the chemical reaction.**

THEODORE J. WILLIAMS, Monsanto Chemical Co.

The general equation of a typical chemical reaction is:

$$nB + mC \rightarrow rD \tag{1}$$

where B, C, and D represent different chemical species, and n, m, and r are the number of molecules of each involved in the reaction. Thus n molecules of compound B simultaneously collide and react with m molecules of compound C to form r molecules of compound D. The formation rate of component D can be written as

$$dD/dt \cong (B)^n (C)^m \tag{2}$$

where (B) and (C) are concentrations of components B and C.

To prove this, consider this simple binary chemical reaction:

$$B + C \rightarrow D. \tag{3}$$

Reaction is brought on by the collision of one molecule of B with one of C; thus, Equation 3 results in:

$$dD/dt \cong (B)(C) \tag{4}$$

However, doubling the number of molecules of B in a given volume doubles the number of collisions, and thus the rate. And since similar considerations also apply to component C, doubling both quadruples the rate.

To remove the proportionality in Equation 2, the right side is multiplied by a reaction coefficient or reaction rate constant k:

$$dD/dt = k(B)^n (C)^m \tag{5}$$

Chemical reactions are usually classified according to their order, which is defined as the sum of the exponents on the reactant concentrations. The order of reaction Equation 1 is $(m + n)$. Thus:

$$\text{Order } (o) = (m + n) \tag{6}$$

The values of m and n, hence the order, are nearly always quite small for commercially important chemical reactions, and the number of product molecules r is usually unity or at most two.

Heat affects chemical reaction

Two heat functions, heat of reaction and activation energy, are important in the study of reaction kinetics and dynamics of chemical reaction vessels. Heat of reaction is chemical energy converted to sensible heat during the reaction. When heat is given off by the reacting materials the reaction is exothermic, and is denoted by a negative sign. When heat is taken up, the reaction is endothermic and has a positive sign.

The reaction coefficient k is an exponential function of temperature. It can often be written as

$$k = Ae^{-E/RT} \text{ or} \tag{7}$$

$$\ln k = \ln A - E/RT \tag{8}$$

Therefore, a graph of k versus $1/T$ on semilogarithmic paper (Figure 1, solid line) is a straight line with a slope $-E/R$ and an intercept A.

The quantity E is activation energy, the minimum energy the molecules of reactants must have on collision to assure reaction; it is positive regardless

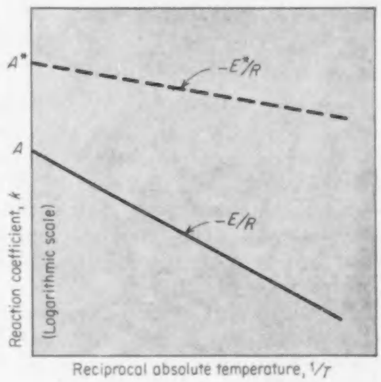


FIG. 1

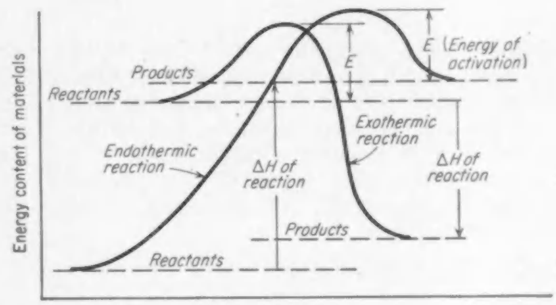


FIG. 2

FIG. 1. Typical variation of reaction coefficient, k, with temperature. The dashed line shows how a reaction-promotion catalyst increases A and decreases the required activation energy E.

FIG. 2. Relationship of activation energy to heat of reaction for typical chemical reactions.

FIG. 3. A typical second-order reaction curve versus time.

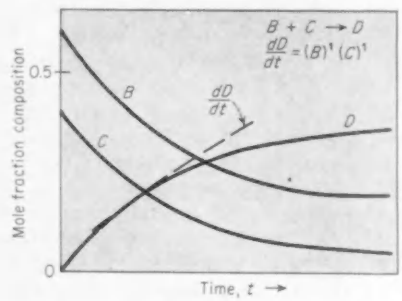


FIG. 3

SYMBOLS

A	Constant in correlation of reaction rate constant
B, C, J, N-	Chemical reactant species
D, L, P	Chemical product species
E	Activation energy
F	Flow rate of liquid streams
G	Constant of proportional valve
ΔH	Heat of reaction
K	Backmixing factor or proportional constant for controller
Q	Heat energy manifested as sensible heat
R	Thermodynamic gas constant; as subscript, refers to reaction mass
S	As subscript, refers to heat storage system
T	Temperature—must be deg absolute in definition of reaction rate constant; otherwise deg C or F; as subscript, refers to total quantity
V	Reactor volume
W	Weight of metal parts of reactor; subscript defines specific parts; as subscript, refers to heat exchanger wall
Z	Displacement of valve stem
a	Area; as subscript, refers to temperature sampler
b, d	As subscript, refers to temperature controller
c	As subscript, refers to coolant flow
e	Base of the Naperian logarithm
f	Function of variable such as f (B); damping ratio of valve
g	As subscript, refers to valve diaphragm
h	Heat transfer coefficient
i	An individual reaction of a group
j	Number of reactor stages
k	Reaction rate constant or reaction coefficient
k_s	Valve spring constant
l	Length
m, n	Number of moles of a reactant taking part in a reaction
o	Order of a chemical reaction; as subscript, refers to reactor output values
p	Differential operator (d/dt)
r	Number of moles of reaction product
s	As subscript, refers to sampler
t	Time
v	Velocity
( )	Incloses symbol of chemical species to indicate composition
ρ	Density, g per cc or lb per cu ft
c_p	Heat capacity
τ	Time constant
ϵ	Error as ϵ(D) or ϵ(T)
ΔP	Pneumatic pressure

of the heat-of-reaction sign, meaning that heat must always be supplied to start the reaction. Figure 2 shows the usual representation of the activation energy for exothermic and endothermic reactions.

The dimensions of k are specified so that the reaction rate (as defined by Equation 5) can be determined in terms of some unit volume. For example, dD/dt may be in terms of grams per cc per min. If concentrations (C) and (B) are expressed as unit volumes, then the dimensions of k are:

$$k = [(\text{time})\ (\text{concentration units})]^{-(o-1)} \tag{9}$$

where o is the reaction order.

If the values of E and A were known, the theoretical determinations of the corresponding values of k would be simple indeed. However, because of limited present knowledge of molecular actions, it is impossible to predict these quantities. The actual values of k must therefore be determined experimentally for at least two, and preferably three or more, different temperatures. Figure 3 gives a typical reaction curve for the reaction stated by Equation 3, where m=1 and n=1. And Equation 10 provides two ways of calculating k:

$$k_t = \frac{\left(\frac{dD}{dt}\right)_t}{[(B)(C)]_t} \text{ or } \frac{D_t}{\int_0^t (B)(C)dt} \tag{10}$$

1. The formation rate of D, dD/dt, is the tangent to the D curve at time t. The values of (B) and (C) must be taken at the point t also. Dividing the tangent by the product of the concentration gives k at time t.

2. When Equation 3 is the correct reaction

mechanism taking place, the second form of the above equation will give a more accurate k value. However, if there is some question as to the accuracy of the assumed mechanism, the first calculation method is better since a regular variation in the resulting values of k as the reaction proceeds will indicate the necessity for developing a new reaction mechanism.

Catalysts and their effects

Most reactions conducted in petroleum refineries and petrochemical and organic chemical manufacturing plants are influenced by a catalyst. This influence may promote or inhibit a specific chemical reaction, depending on the reaction and the catalytic material involved in each case. Catalysts are important here because of the way they affect reaction rate and heat functions. A promoting catalyst has no effect on the value of the process heat of reaction ΔH. However, it will generally increase the value of A and decrease the required value of activation energy E, and do so specifically. That is, it will activate only one of a series of simultaneous reactions or all of them, depending upon its own particular nature. The effect of a promoting catalyst on k is thus generally that shown by the dashed line in Figure 1. E^* is the activation energy in the presence of catalyst.

Several points must be kept in mind concerning catalysts when controlling processes and investigating reactor dynamics: catalysts are subject to poisoning by other substances which in minute quantities nullify or even reverse the catalyst's activating effect; they decrease in activity with time; they are often sensitive to environment (particularly the reaction ambient temperature); and they may be either homogeneous (soluble) or heterogeneous (insoluble) in the reactant mass. The latter are slurried into the reactant liquids or are placed into packed beds through which these liquids flow.

The homogeneous or slurried heterogeneous catalyst affects the dynamics of the reactor only insofar as k is concerned. But a solid heterogeneous catalyst system, with its solid particles, may alter the reactant flow to make the analysis entirely unlike the corresponding unimpeded case.

Successive and simultaneous reactions

So far, processes in which there is only one chemical reaction, and thus only one heat of reaction and one set of reaction coefficient values, have been considered. But there is a large percentage of economically important chemical processes that consist of simultaneous group reactions; and here the amount of desired product depends on the relative rate of the desired reaction to that of the others. In other cases the reactions are successive, and the overall final production rate depends on the rate of the slowest reaction of the series. In still others, the reactions involved may be a combination of the first two types.

As an example of simultaneous reactions, consider:

$$\begin{aligned} B + C &\rightarrow D \\ B + J &\rightarrow L \end{aligned} \tag{11}$$

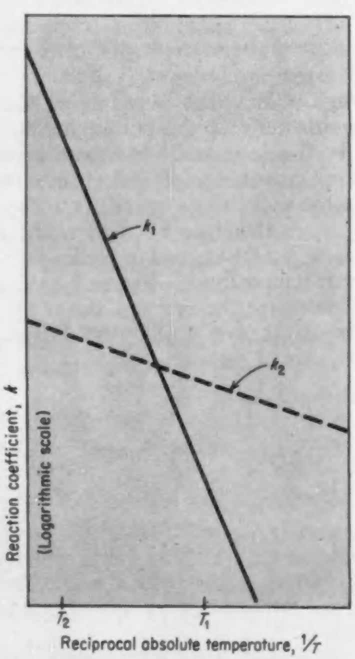
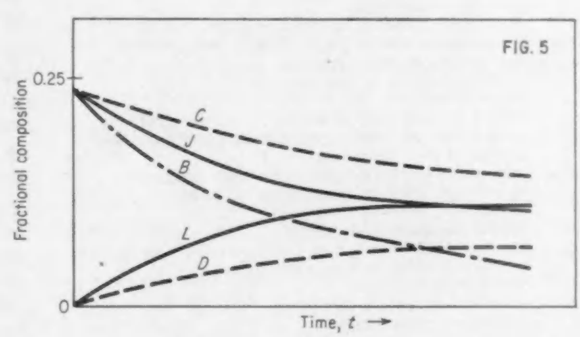
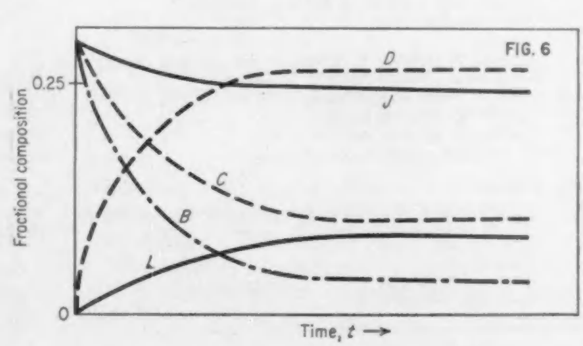


FIG. 4. Reaction rate coefficients for simultaneous reactions show that the reaction operating temperature drastically affects the relationship between the coefficients.





FIGS. 5 and 6. Course of simultaneous reaction of Equation 12 with k values taken at temperature T_1 and T_2 of Figure 4.

When the reactions start with equal amounts of reacting components B, C, and J, the actual amounts of products D and L depend on the relative k values for each reaction:

$$dD/dt = k_1 (B)(C) \text{ and}$$
$$dL/dt = k_2 (B)(J) \qquad (12)$$

Figure 4 defines typical k values. At low temperatures (T_1), k_1 is less than k_2, while at higher temperatures (T_2) the opposite is true. The different rates are reflected in the resulting products of a reaction of equal parts of B, C, and J, as shown in Figures 5 and 6. Figure 6 also reflects the overall faster reaction rate at higher temperature. In this simple case the reaction should be run at the lowest or highest practical temperature, depending on whether L or D is the desired major product.

The following simple pair:

$$B + C \rightarrow D$$
$$D + N \rightarrow P \qquad (13)$$

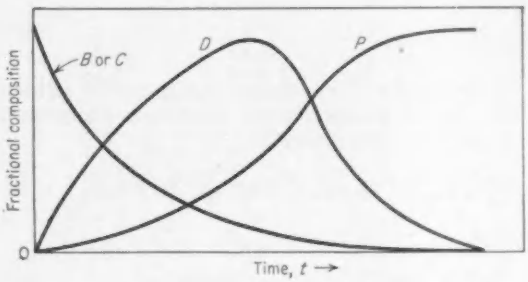


FIG. 7. Course of successive reaction of Equation 13.

serves as an example of successive chemical reactions. A graph of the resulting compositions during a process of this type is given in Figure 7. If the desired product is component D, the operator will stop the reaction when the concentration of D is highest, in contrast to the simultaneous-reaction process, where the reactions go to completion and temperature is the most important variable.

BASIC CHEMICAL REACTOR TYPES AND THEIR DYNAMICS

There are several basic types of chemical reactors in use today; when classified according to their dynamic type, they are found to be: the batch reactor, the single continuous stirred tank reactor, a series of continuous stirred tank reactors, and the tubular or pipe reactor.

Batch reactors

A given amount of each reactant is placed in the batch reactor prior to initiation of any reaction. During the reaction, the reactor is taken through some specified cycle of operation, and upon reaction completion the product materials are removed, the reactor is cleaned, and the complete procedure is repeated.

A major problem in batch reactor operation is determining the optimum temperature vs. time cycle to yield maximum desired product and minimum undesired byproducts. The temperature-time cycle is best worked out in a complex case by a successive trial and error solution (on a computer) of the differential equations defining the kinetic and dynamic relationships involved. Automatically controlling the reactor then becomes a problem of so controlling heat energy addition or removal that this optimum cycle is adhered to as closely as possible.

Figure 8 diagrams those functions that must be accounted for in writing the set of differential equations specifying the reactor's dynamics and its automatic control. These equations, derived below, accompany the assumptions of Table I. Any failure of applicability in these assumptions greatly complicates analysis.

Any set of simultaneous equations describing a reaction system includes one composition-change equation for each separate chemical species utilized or formed in the chemical reactions comprising the process. These equations will be similar to Equation 5. Other equations correspond to each separate chemical reaction, and define the sensible heat changes arising from the process heats of reaction. Since concentrations are given as weight or molar units per unit volume of reactor, the rate of heat gain to the complete reactor system for each reaction equation can be expressed in the form:

$$\frac{dQ_i}{dt} = -V\frac{d(D)}{dt}\Delta H \qquad (14)$$

where D is the product formed by the reaction. Here, ΔH is the change in internal energy during the reaction for each weight or molar unit of product formed. The sign is negative to compensate for the sign convention of ΔH. Therefore:

$$\frac{dQ_T}{dt} = \sum \frac{dQ_i}{dt} \qquad (15)$$

accounts for the heat produced by all reactions taking place at one time. The resulting heat gain or loss has the potential of changing temperature by an amount:

$$\frac{dT}{dt} = \frac{1}{V\rho c_p}\frac{dQ_T}{dt} \qquad (16)$$

However, as Figure 8 shows, there is also heat

TABLE I COMMON ASSUMPTIONS MADE IN CHEMICAL REACTOR DYNAMIC ANALYSES

1. *Batch and continuous stirred tank reactors are perfectly mixed: there are no temperature or concentration gradients.*
2. *The heat transfer coefficient between reacting materials and heat exchanger or heat storage walls is a constant. So is the coefficient between heat exchanger walls and heat exchanger fluid.*
3. *Temperatures of the heat exchanger wall and of the heat storage metal parts are uniform, although not necessarily equal.*
4. *There is no volume or density change on reaction.*

interchange with the energy storage system and with the heat exchange system. Therefore, Equation 16 must be modified accordingly:

$$\underset{\mathrm{I}}{\frac{dQ_T}{dt} = V_R \rho c_p \frac{dT_R}{dt}} + \underset{\mathrm{II}}{W_S c_p \frac{dT_S}{dt}} + \underset{\mathrm{III}}{W_W c_p \frac{dT_W}{dt}} + \underset{\mathrm{IV}}{F_c c_p (T_{c_o} - T_{c_{in}})} \tag{17}$$

Here I represents energy manifested as a temperature change in the reaction mass; II represents energy appearing as a temperature change in all of the heat storage parts of the reactor except the wall of the heat exchanger; III is energy storage in the heat exchanger wall; and IV is energy transferred to or from the heat exchange medium. The fact that items II, III, IV are rate limited by the basic laws of heat transfer add complexity:

$$\frac{dQ_S}{dt} = h_R a_S (T_R - T_S) \tag{18}$$

$$\frac{dT_S}{dt} = \frac{h_R a_S (T_R - T_S)}{W_S c_p} \tag{19}$$

$$\frac{dT_W}{dt} = \frac{h_R a_W (T_R - T_W)}{W_W c_p} \tag{20}$$

$$F_c c_p (T_{c_o} - T_{c_{in}}) = h_c a_W (T_W - T_{c_o})$$

$$T_{co} = \frac{(h_c a_W T_W) + (F_c c_p T_{c_{in}})}{(F_c c_p) + (h_c a_W)} \tag{21}$$

The term a_S represents the total area of reactor surface, including such things as stirrers, sampling tubes, and covers—but less that area a_W directly associated with the heat exchange system.

The heat transfer coefficient h is in appropriate units: cal per sq cm-deg C-sec or Btu per sq ft-deg F-hr.

The objective in batch reactor control is to make the reaction mass temperature follow as closely as possible some optimum temperature-time profile. This is done by varying the flow rate of a heating or cooling medium (or both) in the heat exchanger jackets during the reaction. A three-hour temperature-time cycle like the one in Figure 9 determines the set-point of the reactor controller; the heat exchange surfaces then must provide the required heat transfer rates and the heat storage parts must not cause harmful overshooting of temperature limits.

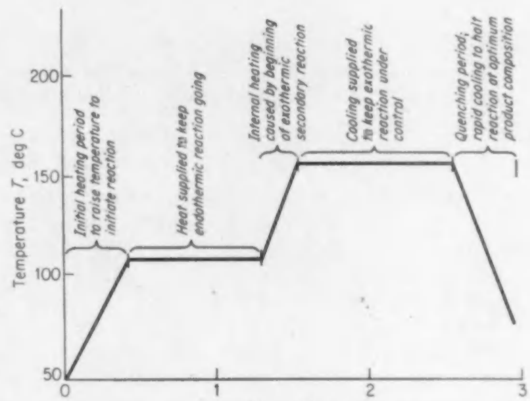
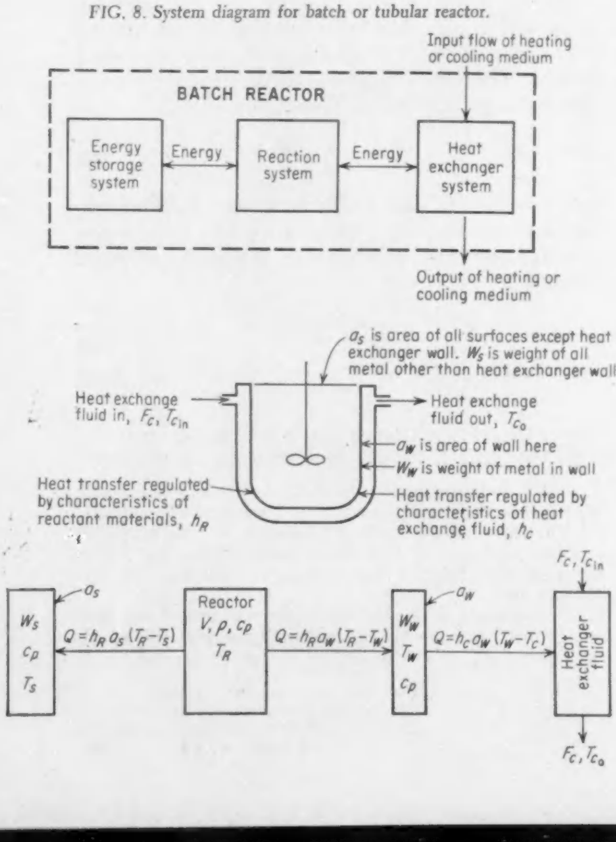


FIG. 9. Typical temperature vs. time cycle for a batch reactor.

FIG. 8. System diagram for batch or tubular reactor.



Continuous stirred tank reactors

The high price paid in time and labor in charging and emptying each cycle make the batch reactor expensive to operate. The continuous stirred tank reactor was conceived in an effort to eliminate such costs and thus lower the total production cost of chemical materials. Such reactors, Figure 10, can be used singly or in series.

The continuous stirred reactor has one complexity—the continuous mixing of fresh reactant materials into the reactant mass—that the batch reactor does not have. This completely changes the type of control needed. Instead of controlling the temperature profile with time, the continuous stirred tank reactor is brought up to and controlled at that unique temperature providing the optimum in economy for the process involved.

The best way to derive equations defining the concentration of various chemical species in this reactor type is to make a material balance of the amount of each chemical species entering or leaving the reactor and taking part in a chemical reaction within it. Material balance equations are of the type:

$$\frac{d\,(B)}{dt} = \frac{F_{in}}{V\rho}(B)_{in} - \frac{F}{V\rho}(B)_o - kf\,(B) \tag{22}$$

which sums the gains and losses of component B with time. One such equation must be written for

each reactant and each product in the reaction process.

The generation and transfer of heat in this reactor is represented in the same way as it is in the batch reactor, except that the following term is added to Equation 17 to account for the difference in sensible heat of the input reactant streams and the output product stream:

$$Fc_p\,(T_R - T_{in}) \tag{23}$$

A series of continuous stirred reactors will counteract the degradation of yield resulting from using one such reaction vessel in which the reactants will not be able to stay long enough to complete the reaction. Theoretically, an infinite number of continuous reactors achieves the maximum yield possible with a batch reactor; however, in actual practice four or five will give nearly the same results.

Determining the behavior of a reactor series amounts to duplicating each of the equations required for the single reactor, for each reactor in series, and then solving the whole group simultaneously. This analysis increases in difficulty as the number of reactors and reaction complexity increases, and demands an extensive computer facility to carry out the solution.

Tubular reactors

By means of its continuous operation, the tubular (or pipe) reactor, Figure 11, can prevent a reduction in yield resulting from, say, an unwanted byproduct formed by a secondary reaction between the main product and an original reactant. When the reactants flow through a long, very narrow pipe at a velocity sufficient to cause turbulence (at least 0.5 ft per sec), complete lateral mixing occurs with little or no longitudinal mixing. Such a flow is known as plug flow.

The perfect tubular reactor has a direct relationship between time and length along the reactor for a given flow velocity. Its system diagram, Figure 8, is the same as that for a batch reactor. For a particular

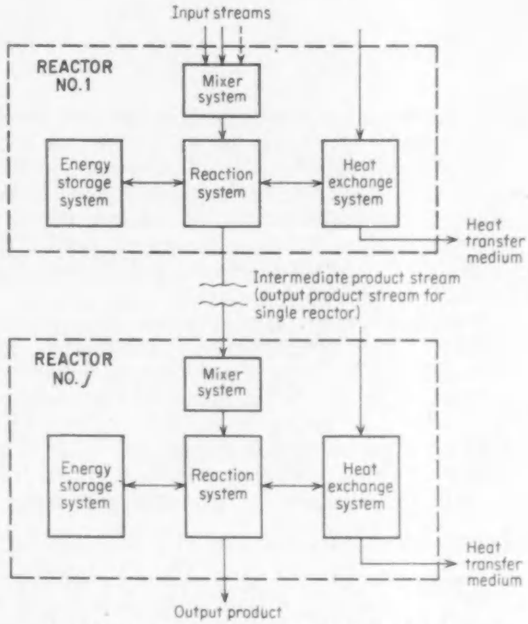


FIG. 10. System diagram for a series of continuous stirred tank reactors. The top block describes one reactor.

rate of composition change with time in a batch reactor, there is a corresponding rate of composition change with length in the tubular reactor, related by flow velocity:

$$\frac{dD}{dt} \times \frac{l}{v} = \frac{dD}{dt} \times \frac{dt}{dl} = \frac{dD}{dl} \tag{24}$$

There is no mixing of product with reactants in the perfect tubular reactor because there is no longitudinal mixing. The kinetic equations are therefore the same as for a batch reaction except for the change of *dt* terms to *dl* terms. The tubular reactor must be maintained at the same temperature profile as for the equivalent batch reaction to secure the optimum reaction yield. Now, however, the profile is expressed as some specific temperature-length distribution along the tube.

The desired continuously varying temperature pro-

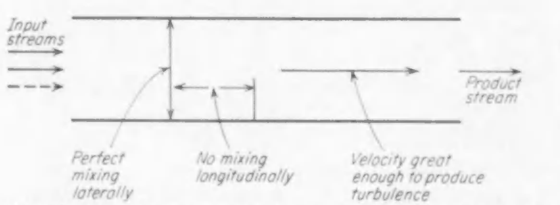


FIG. 11. System diagram of the perfect (no backmixing) tubular reactor.

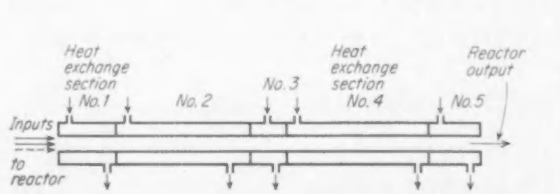


FIG. 12. A five-section heat exchanger arrangement for the perfect tubular reactor providing the temperature-length profile shown in Figure 13.

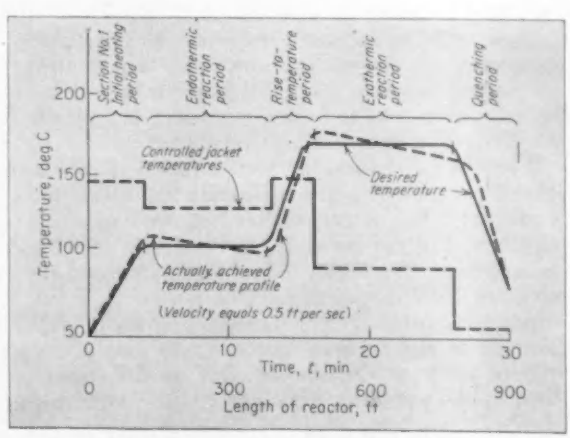


FIG. 13. Comparison of actual and desired temperature-length profile for a reaction carried out in the tubular reactor.

file, unobtainable by any practical means, can be approximated by making the reactor tube the inner one of a concentric-tube heat exchanger and then dividing the shell side into sections, Figure 12, each having a separately controlled temperature. Figure 13 graphs the desired temperature-length profile, the shell side temperature pattern, and the resulting actual temperature-length profile.

Note that a much shorter reaction period is indicated in Figure 13 than for the similar batch reaction of Figure 9. This brings out the chief drawback of the perfect tubular reactor: since the turbulent flow required for mixing necessitates a velocity of at least 0.5 ft per sec, a slow reaction will demand an enormously long pipe. And unfortunately, most organic chemical reactions are generally quite slow.

Imperfect tubular reactors and backmixing

If economics or practicality prohibits a sufficiently long tubular reactor, it may be approximated by a shorter, larger diameter tube equipped with internal mechanical or high-velocity gas mixing. There is this drawback to such an arrangement: it causes backmixing, a form of longitudinal mixing in which a fractional amount K of reacted material is carried backward in the tube, contacting fresh or unreacted feed stock, and forming unwanted by-products. Backmixing in tubular reactors is usually less than in a series of stirred reactors and considerably less than in one. In fact, the continuous stirred tank reactor could be considered a 100-percent backmixed reactor.

The equations describing the imperfect tubular reactor will thus be like those for the series of stirred tank reactors, but with a term added for backmixing:

$$\left[\frac{d\,(B)}{dt}\right]_i = \left[\frac{F_{in}}{V}\,(B)_{in}\right]_i - \left[\frac{(F_o + KF_o)}{V}\,(B)_o\right]_i - kf\,(B)_i + KF_o(B)_{i+1} \qquad (25)$$

Likewise, the following terms (corresponding to Equations 17 plus 23) accounts for the addition of backmixed-stream sensible heat to the section:

$$[KFc_p(T_R - T_{R_{i+1}})] \qquad (26)$$

As before, one equation like Equation 25 is needed for each component for each section; and one like 17 plus 23 plus 26 is needed for each section.

AUTOMATIC CONTROL OF CHEMICAL REACTORS

Previous investigations of reactor control (Refs. 1, 2, 3, 4, 5, 8) established factors which will be the basis of further study of chemical reactor dynamics and automatic control. These factors, Table II, assume that a theoretical rather than an experimental approach will be taken in all future work in this field. Such an assumption is based upon those points brought out in Table III.

The most direct way to attack the problem once an adequate computer is procured is through mathematical simulation. A set of ordinary differential equations describing the complete system (including the control device) is programmed into the (analog) computer, and the resulting simulation then is subjected to representative inputs, and its resulting response is recorded from the computer output onto a multichannel recorder. The simulated controller can be adjusted essentially like a plant controller; thus the optimum setting can be obtained directly by a trial and error procedure and by the methods of statistical design of experiments.

Frequency responses can also be found by simulation, by means of sinusoidal inputs applied to the computer. Thus a complete control study of a particular reactor can be made, provided only that the assumptions upon which the simulation is based are accurate. This latter can only be proven by direct experiment, however, which means that some small amount of experimental data is vitally needed for all computer simulations—at least until complete trust can be put in the assumptions used in deriving the basic equations.

Analyzing a reactor and its controls

Figures 14 and 15 on page 108, the schematic and block diagrams for a continuous stirred tank reactor, illustrate the degree of complexity of even the simplest reactor system simulation required for process control studies. It is desired to react two liquid streams, F_1 and F_2, whose combination exhibits a highly exothermic reaction. To avoid side reactions an upper limit is placed on the allowed reaction temperature. And, since a maximum product is desired, stream F_1 will be controlled from the reactor output product composition while F_2 is ratio-controlled (not shown) from F_1.

An analysis should include such things as valve diaphragm and shaft responses, actual rather than ideal controller functions, and lags of sampling devices, and should allow for variations in flow of the primary reactant fluid, in input reactants temperatures, and in coolant temperature.

The reaction equations, from Figure 14, are:

$$B + C \rightarrow 2D \qquad (27)$$

$$V\frac{d(B)}{dt} = F_1(B)_1 - (F_1 + F_2)\,(B)_o - Vk\,(B)_o(C)_o \qquad (28)$$

$$V\frac{d(C)}{dt} = F_2(C)_2 - (F_1 + F_2)\,(C)_o - Vk\,(B)_o(C)_o \qquad (29)$$

$$V\frac{d(D)}{dt} = V\frac{d(B)}{dt} + V\frac{d(C)}{dt} - F_o(D)_o \qquad (30)$$

$$k = f\,(T_o) \qquad (31)$$

The heat balance will be:

TABLE II FACTORS IN THE FUTURE ANALYSIS OF CHEMICAL REACTOR AUTOMATIC CONTROL PROBLEMS

1. The complete nonlinear equations of the system must be considered; i.e., the effects of temperature, concentration, and possible interfering foreign substances must be taken into account in deriving system equations.
2. The resulting large number of simultaneous equations involved and their inherent nonlinearities require computers to obtain solutions in a reasonable time.
3. Either digital or analog computers may be used. However, analogs offer several advantages if the system to be simulated does not exceed the capacity of the available machine.

TABLE III DISADVANTAGES OF EXPERIMENTAL DETERMINATION OF CHEMICAL REACTOR DYNAMICS AND CONTROL BEHAVIOR

1. Most chemical plant equipment is needed constantly in normal production. Its use for experimental testing would thus mean taking it off-stream.
2. Much chemical plant equipment is quite large and thus uses a sizable inventory of material for operation. Since a majority of chemical materials are relatively high-priced, a large investment in plants and inventory is necessary for experiments.
3. Large-scale plant equipment is usually quite sluggish; a large amount of experimental time would therefore be necessary to completely determine response to a variety of input disturbances.
4. Since response testing involves testing the stability of the plant reactor system to various inputs, the possibility is always present of causing an instability, or even damaging the system.
5. Because each piece of equipment can only be tested over a limited range of variables, a complete study of a reactor's response would require testing several reactors of different sizes and shapes.

$$\begin{aligned}\frac{dQ}{dt} = V\rho c_p \frac{dT_o}{dt} + W_S c_p \frac{dT_S}{dt} + W_W c_p \frac{dT_W}{dt} \\ + F_c c_p (T_{c_o} - T_{c_{in}}) + F_1 c_p (T_o - T_1) \\ + F_2 c_p (T_o - T_2) = -V \frac{d(D)}{dt} \Delta H \end{aligned} \tag{32}$$

from Equation 17. Following the pattern established earlier, certain terms of Equation 32 are defined by Equations 19, 20, and 21, thus leaving T_o as the basic variable to be defined by Equation 32.

The output composition for (D) is sampled in relation to (B) and (C), and the relative completion of the reaction is then determined. Cutting down flow F_1 increases the effective residence time of material in the reactor and thus increases the conversion of reactants to product. However, this also cuts down the reactor's overall yield. Thus there is an optimum economic level of product (D) in the output stream.

The control equations for the composition loop are:

$$\frac{(D)_S}{(D)} = \frac{1}{\tau_1 p + 1} \tag{33}$$

where τ_1 is the composition-sampler time constant.

$$\epsilon(D) = [(D) - (D)_{set\text{-}point}] \tag{34}$$

$$\frac{\Delta P_1}{\epsilon(D)} = K_1 \left(\frac{\tau_2 p + 1}{\tau_2 \alpha p + 1}\right) \frac{\tau_3 p + 1}{\tau_3 \beta p + 1} \tag{35}$$

Here α is the derivative-control constant, β is the integral-control constant, and K_1 is the proportional-control constant, terms well-known to the control engineer.

$$\frac{\Delta P_2}{\Delta P_1} = \frac{1}{\tau_g p + 1} \tag{36}$$

where τ_g is the valve diaphragm time constant.

$$\Delta P_2 = M \frac{d^2 Z}{dt^2} + f \frac{dZ}{dt} + K_S Z \tag{37}$$

is the second-order differential equation representing valve operation.

Finally,

$$F_1 = (1 + Z) F_1' \tag{38}$$

if one considers Z as a correction to a preset valve opening controlling the input flow F_1.

There is a similar set of equations for the temperature loop:

$$\frac{T_{o_s}}{T_o} = \frac{1}{\tau_a p + 1} \tag{39}$$

where τ_a is the temperature detector's time constant.

$$\epsilon(T_o) = (T_o - T_{set\text{-}point}) \tag{40}$$

$$\frac{\Delta P_a}{\epsilon(T)_o} = K_b \cdot \frac{\tau_b p + 1}{\tau_b \alpha p + 1} \cdot \frac{\tau_d p + 1}{\tau_d \beta p + 1} \tag{41}$$

$$\frac{\Delta P_b}{\Delta P_a} = \frac{1}{\tau_g p + 1} \tag{42}$$

$$\Delta P_b = M \frac{d^2 Z}{dt} + f \frac{dZ}{dt} + K_S Z \tag{43}$$

Finally, $F_c = GZ$

Here Z is considered as controlling the total flow of the coolant stream.

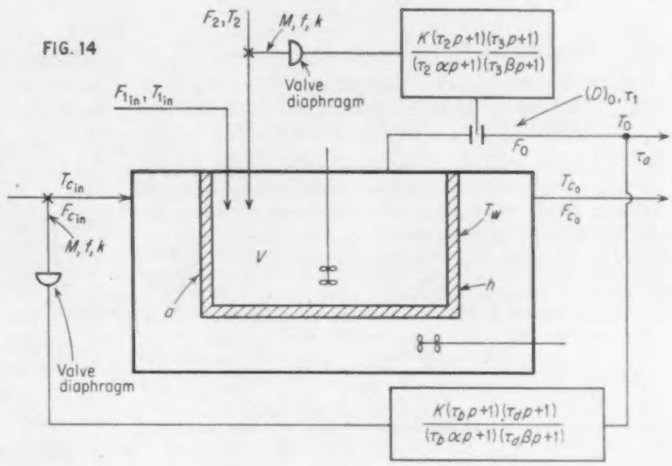
Simulating this simple reaction requires that 20 equations be programmed in the computer:

- ▶ Reaction Equations 28, 29, 30 and 31
- ▶ Heat balance Equation 32 and subsidiary Equations 19, 20, and 21
- ▶ Composition control Equations 33, 34, 35, 36, 37, and 38
- ▶ Temperature control Equations 39, 40, 41, 42, 43, and 44

A directed trial and error procedure on the computer establishes the proper settings of controller constants α, β, and K to give the best control for each particular configuration of controller and reactant materials to be considered. Input variations to be tested include upsets in F_1', T_1, and T_c.

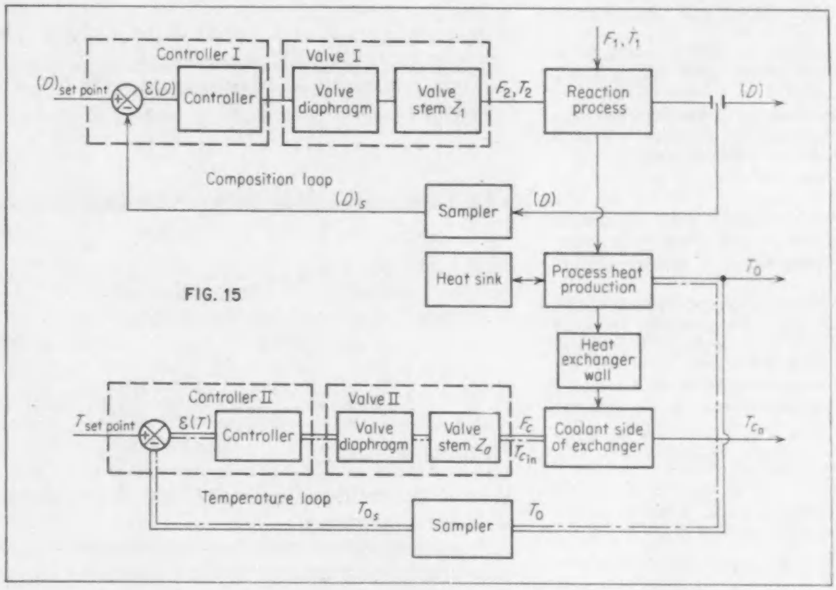
The preceding sample problem is not to be considered an optimum reactor control configuration; it is presented here only as a discussion point. The actual configuration to be chosen in each case is a very definite function of the kinetics and the heat of reaction of the particular chemical reaction to be

FIG. 14



FIGS. 14 and 15. Continuous stirred reactor and associated control system.

FIG. 15



controlled. There are certain combinations of reactor and reactant parameters for which the composition control used here is very satisfactory. On the other hand, particularly for cases of small E and large ΔH, where very small changes in composition represent very great changes in heat production and thus of reaction rate, i.e., where F_1 is dependent on T_o rather than $(D)_o$, an entirely different control arrangement is necessary. Each case should therefore, be worked out on its own merits, at least until overall knowledge of kinetics and chemical reactor dynamics becomes more extensive.

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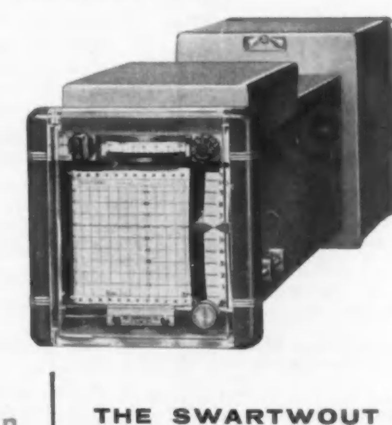

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- Almost perfect mating of available power transistors to the dc motor
- A range in torque-speed characteristics of dc motors that simplifies or eliminates gearing
- Very small stand-by power; in ac servos, stand-by power often is almost as large as full-load power

But servos often need automatic gain control, and this has been a great deal simpler with ac servos. Figure 1 is a servo arrangement for obtaining the reciprocal of a process variable. For values of Z between 1 and 100 volts the nulling action of the servo maintains the feedback voltage from the potentiometer at 1 volt as Z is varied. The shaft rotation is then proportional to the reciprocal of Z, as indicated by the output voltage from the second potentiometer section. As the variable Z becomes smaller, the closed-loop gain of the servo decreases, and the time constant and error of the servo becomes larger. It can be seen that without AGC the servo will fail to perform adequately at low values of the Z variable. AGC is also needed in a resolving servo employing sine-cosine potentiometers to perform inverse resolution, i.e., vector addition.

In ac servos, AGC is usually provided by feedback to a remote cut-off pentode. The Z variable is smoothed and summed with the input error signal, and as Z becomes smaller the bias on the remote cut-off pentode is reduced and the gain of that tube is correspondingly increased. However, this variable bias to obtain variable gain is not usable in dc servos. Here not only the gain but the dc level is changed by the AGC action, and the servoamplifier is unable to distinguish between changes in level due to the dc signal and those due to the AGC voltage.

A method of obtaining AGC

One way to solve the problem is to place a dc feedback amplifier in the forward-gain portion of the servo, Figure 2. This amplifier has a feedback conductance proportional to the Z variable. If the gain of the amplifier without feedback is large compared to its gain with feedback, the net gain with feedback is inversely proportional to the conductance of the feedback resistance used. Then it is necessary to use a conductance that:

- is directly proportional to an externally applied variable-controlling voltage
- will follow rapid fluctuations in the applied controlling voltage
- is independent of the current flowing through it
- is free of voltages induced by the controlling signal, and
- is independent of operating temperature variations

These requirements are met satisfactorily by the circuit shown in Figure 3. It consists essentially of a small neon lamp and a cadmium selenide photo conductive cell mounted close together in a light-tight enclosure. The cell has fairly linear photoconductive characteristics over a wide range, negligible photovoltaic effect, small temperature coefficient in the normal ambient range, and generally meets the above requirements. Because the neon lamp is a constant-voltage device when ionized, its light intensity is proportional to the lamp current. The AGC voltage is connected to the lamp through a large series resistance, making the light intensity and the cell conductance proportional to the voltage magnitude. A small keep-alive current is supplied to the lamp from the positive reference source to maintain ionization.

This circuit provides excellent AGC by maintaining amplifier gain within plus or minus 1 db over a 20-to-1 range of the Z variable. It is not measurably affected over an ambient temperature range of 25 to 70 deg C. The circuit has exhibited better performance and more reliability than the corresponding ac AGC method. Thus, a former limitation in the use of dc instrument servos may now be listed as an advantage. In systems where signals can, should, or must be dc, dc servos can give better performance, reliability, and efficiency with small size.

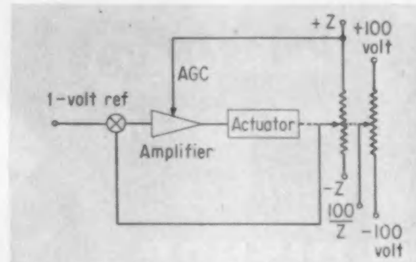

FIG. 1. Servomechanism for computing reciprocal of variable Z needs automatic gain control to maintain accuracy for small values of Z.

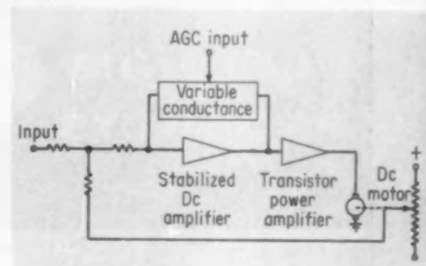

FIG. 2. Feedback via a variable conductance element can successfully add AGC to dc servos.

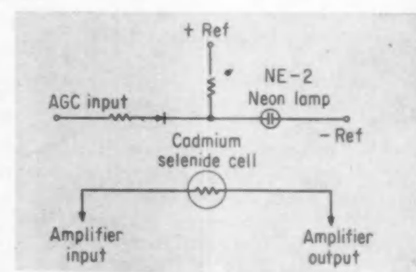

FIG. 3. Photoelectric control of variable conductance is unique solution for dc servo AGC.

Three Ideas at Work in Machine Control

Performance-improving, money saving new ideas for control engineers from machine builders, excerpted from the recent 22nd Machine Tool Electrification Forum, sponsored annually by Westinghouse.

1. Inexpensive, High-Response 1⅔-Hp Servos

ROBERT H. EISENGREIN
Seneca Falls Machine Co.

Slide- and carriage-positioning control systems for today's machine tools must perform with high accuracy and guaranteed repeatability. And when they are servoed to produce the position called for by a contour tracing transducer or any other program source, they must have better dynamic response at higher power levels than ever before. An electromechanical control system has been developed that satisfies all these requirements in a relatively simple, inexpensive way. It has instrument-type response at integral-horsepower output levels.

The electronic controller represents a simple means of amplifying the normally low-level electrical signals available from existing transducers, and an equally simple means of mixing signals, matching signal sources to loads, and utilizing the outputs of most computer systems. The problem is the electromechanical conversion.

The two-phase induction motor—workhorse of the instrument servo field—is designed specifically for high speeds of response. It has been proven in use, and its characteristics are understood analytically. In addition, the power required to control it is low enough so that electronic, magnetic, or transistor amplifiers can drive it. But the low mechanical power output of such a servomotor has to be amplified into the horsepower range. A program was started a few years ago to develop a mechanical power amplifier for this purpose. Figure 1 is a schematic drawing of the result.

In Figure 1, each drum is a "windlass" turned by a source of prime mechanical power, a properly sized ac motor. Each drum has a flat band wrapped around it several times. One end of each band is connected to a load; the other end provides the means for control. When no force is exerted on the input end of a band, maximum slip exists between the band and the drum and no output force exists. As a force is exerted on the input end of a band in the direction shown by the arrows, an amplified force appears at the output end. The available power to move the load comes from the drum. In this simple arrangement, any output rotation always equals the input rotation; the output force is a multiple of the input force. Two drums are mounted back to back to obtain the bidirectional output needed in servo systems. The input control torque is supplied by a low-power two-phase servomotor.

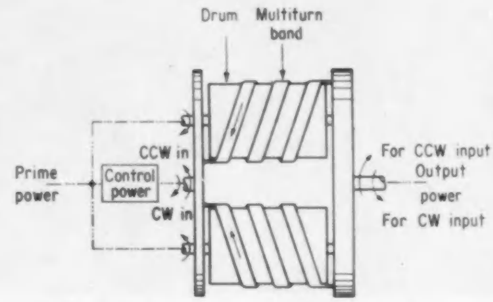

FIG. 1. Two-drum mechanical amplifier is bidirectional, has theoretical maximum acceleration over 80,000 radians per sec². In practice, acceleration is limited by control servomotor.

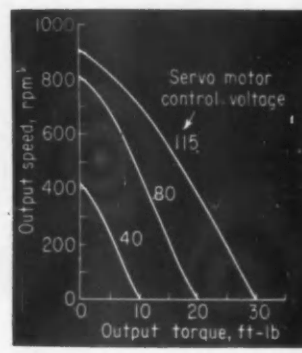

FIG. 2. Speed-torque characteristics of 1.66-hp mechanical amplifier show same shape as those for the control servomotor used.

The actual mechanical power amplifier is rated for a maximum of 1.66 hp. Its characteristics, Figure 2, are the familiar family of curves of a two-phase induction motor designed for servo-system operation. The maximum torque-to-inertia ratio at the output shaft is limited by the input servomotor used; here it is 1,400 radians/sec². (The theoretical output torque-to-inertia ratio is over 60 times this value.) Again, for the unit under discussion, the frequency response of the overall system is the same as the frequency response of the input servomotor used.

For systems requiring better frequency response than obtainable with the 60-cps servomotor normally used, it is only necessary to substitute a 400-cps servomotor and excite the input transducer with a 400-cps voltage. The 400-cps power required is only 20 to 30 watts and may be obtained easily from a transistor oscillator or a small permanent magnet generator.

Two mechanical power amplifiers, presently being used in the field, are rated at 0.8 and 1.6 hp. These units have logged thousands of hours of successful operation in an environment of dirt, coolant, and chips. Other horsepower ratings will be made available as the need arises.

2. Simplified Circuitry for Remote Controls

Ingersoll Milling Machine Co.
E. K. WAGNER

Reduction of the number of control connections leading out of a remote control station is often desirable. In very large machine tool installations, the operator usually has to be able to move quite freely while controlling the machine in order to get a good view of the work. In such cases, the remote control station must also be portable, and usually is a pendant at the end of its connecting cable.

Conventional relay control circuitry for a certain large adjustable-rail milling machine required that the pendant control be connected to the main control by 84 conductors encased in a 3-in. flexible steel cable. Portability of the pendant was questionable. However, a new control circuit reduces the conductors to 22.

The new circuit is shown in elementary form in Figure 1. G_1, G_2, and G_3 are dc sources with polarities as indicated, and the output of G_3 equals the sum of G_1 and G_2. G_1 furnishes current to give a 4-volt drop across each of resistors R_1, R_2, and R_3. Similarly, G_2 furnishes an 8-volt drop across each of resistors R_4, R_5, and R_6. The resistance of RA is equal to one-half that of RB. Resistors RC_1, RC_2, and RC_3 limit the current through RA and RB so that when switch S_3 is closed, a 12-volt drop occurs across RA, and a 24-volt drop occurs across RB. With S_2 closed, there is an 8-volt drop across RA and a 16-volt drop across RB. Similarly, closing S_1 develops 4 volts across RA, 8 across RB.

When the switches are closed individually, the potentials of the various terminals with respect to the common point, K, are as follows:

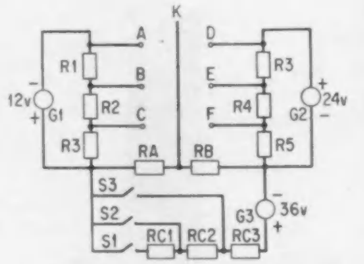

FIG. 1. Basic circuit used to simplify pendant remote control for large milling machine.

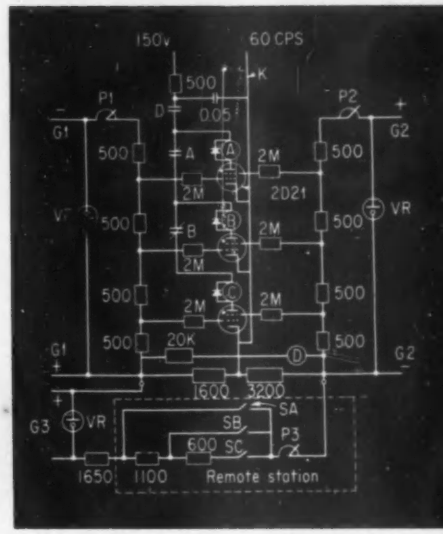

FIG. 2. Lettered terminals in Figure 1 connect to grids of dual-grid thyratrons. Two wires can control up to 12 relays.

SWITCH 1 CLOSED

Drop across $RA = 4$; across $RB = 8$.

$A, -12+4=-8$	$D, +24-8=+16$
$B, -8+4=-4$	$E, +16-8=+8$
$C, -4+4=0$	$F, +8-8=0$

SWITCH 2 CLOSED

Drop across $RA = 8$; across $RB = 16$

$A, -12+8=-4$	$D, +24-16=+8$
$B, -8+8=0$	$E, +16-16=0$
$C, -4=+8=+4$	$F, +8-16=-8$

SWITCH 3 CLOSED

Drop across $RA = 12$; across $RB = 24$

$A, -12+12=0$	$D, +24-24=-0$
$B, -8+12=+4$	$E, +16-24=-8$
$C, -4+12=+8$	$F, +8-24=-16$

Note that for each switch there is one pair of terminals at zero potential with respect to K; all other pairs have one negative terminal. By connecting each of these pairs to the two grids of a dual-control-grid thyratron (2D21), only the particular tube with both grids at zero potential with respect to its cathode (point K) will conduct.

Figure 2 shows such a circuit using three 2D21's (as many as 12 can be used in this type of circuit). Note that only a single pair of wires is needed to connect the switches (up to 12) to the tube portion of the circuit. The plate supply for the thyratrons is supplied by a 150-volt, 60-cps transformer. The pilot relays in the plate circuits are of the telephone type, with 1,300-ohm coils, and have copper slugs that give 30- to 50-millisec delay on activation. The delay is intended to protect against transients, but may not be necessary. A 50-ma, 150-volt selenium rectifier across each relay coil prevents chattering.

A normally-closed contact on each plate relay opens all plate supplies to tubes which have positive voltages on their control grids. High-resistance relay D opens the plate supply to the thyratrons in case of a break in the pendant cable. Potentiometers P_1, P_2, and P_3 are used to compensate for variations in the VR tubes. Switches are of the snap-action type to prevent triggering the thyratrons falsely due to varying contact resistance during closure of directly-actuated switches.

This circuit permits the use of only three wires and the common return ($-G_3$) to handle the 27 pushbutton switches used on the milling machine mentioned above. The other 18 wires in the new remote control cable are used for toggle-switch circuits. This number is about half that necessary originally, because junction-diode rectifiers and an ac supply have been used to get polarized relay selection.

3. New Ac Adjustable-Speed Motor Principle

W. R. HARDING
Westinghouse Electric Corp.

Rectiflow drives represent an entirely new concept in packaged ac adjustable-speed drives. Basically, they consist of a wound-rotor induction motor and a dc motor built on a common output shaft. Associated with these two motors in the basic package is a set of semiconductor rectifiers that convert the ac slip power of the wound-rotor motor to direct current. This dc power is supplied to the armature of the dc motor, as in Figure 1.

An additional group of rectifiers converts ac from the incoming power line to dc for the dc motor shunt field. Speed can be controlled simply by controlling the field of the dc motor.

In the Rectiflow system:

• The dc motor converts the slip power to mechanical power output. Conventionally, this slip power has not been available.

• The separately excited field circuit of the dc motor permits speed control.

• Speed range is determined by the base speed of the dc motor and the relationship of its rated voltage to the induction motor rotor voltage.

Certain interesting variations are possible. For example, regulators added to the dc circuit can give various performance characteristics similar to those for typical dc motors.

For the ac motor portion of the basic Rectiflow drive, the operation is like that of a conventional wound-rotor motor. But a counter-emf generated by the dc motor bucks the rectified ac rotor circuit voltage, and the difference between these voltages is such that the latter is just sufficient to circulate load current through the ac rotor, the rectifier, and the dc armature. A weakened dc motor field means less counter-emf and more current. This in turn means more torque in both ac and dc machines, and the drive accelerates to a higher speed. As the speed increases the rotor slip voltage decreases and the counter-emf increases; therefore, acceleration ceases when these voltages differ by the amount required to circulate running load current at the new speed.

Starting torque of Rectiflow drives is a maximum of 600 percent of full load values when full line voltage is applied on the primary of the wound rotor and full field is applied to the dc motor. Variations down to 25 percent of normal starting torque can be obtained by using double-delta windings on the primary of the wound-rotor motor. Very smooth starts are obtained by exciting the dc field at the same time as the ac contactor is closed. The time constant of the dc field allows a smooth build-up of torque. Figure 2 shows the various characteristics for a 125-hp Rectiflow drive.

In the basic drive, the combined characteristics of the wound-rotor motor and the shunt-wound dc motor yield inherent constant horsepower. But by use of proper dc motor characteristics and selection of proper frame sizes, an economical and effective constant-torque drive is possible, too. In drives designed for constant torque, the torques developed are cumulative on the common shaft.

Rectiflow drives have been developed and are now available in 1½ to 1, 2 to 1, and 3 to 1 speed ranges, for both constant-horsepower and constant-torque applications. Units can be drip-proof, force-ventilated, or totally enclosed fan-cooled. Drives rated from 7½ hp to 75 hp are built as a unit frame; so are drives in smaller ratings, that are now being developed. Above 75 hp, separate units will be coupled on a common bedplate. Speed regulation over the range is approximately 7½ percent, with an efficiency at full load of 85 percent.

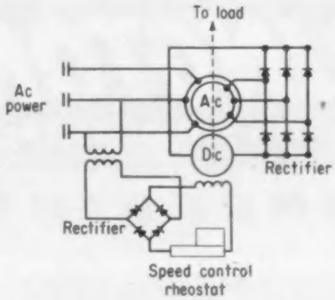

FIG. 1. Schematic diagram showing system in which ac slip power from wound-rotor motor is rectified by semiconductor rectifiers and supplied to armature of a direct-coupled dc motor.

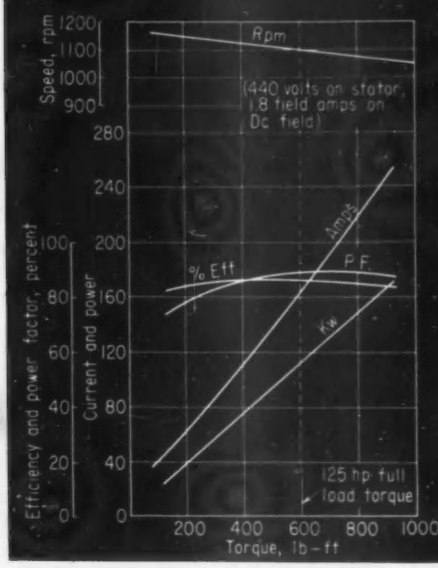

FIG. 2. Efficiency, power factor, speed, current, and power plotted against torque for a 125-hp Rectiflow adjustable-speed drive.

"Auctioneer" Controls Atomic Reactor Coolant Temperature

H. A. POWERS
Norwood Controls

Pressurized-water atomic power reactors have several coolant circuits. The average temperature of the hottest of these circuits must be used for coolant temperature control. This article describes a simple electromechanical solution that gives control "to the highest bidder".

The "pressurized water reactor" is the most common commercial atomic power reactor. In the PWR water circulates around the fuel elements to absorb the heat generated by nuclear fission. This water is about 525 deg F at 2,000 psig; hence the name PWR. It emerges from the reactor up to 50 deg F hotter than it entered, depending on the power demand, and the heat thus gained is dissipated in a heat exchanger to convert feed water into steam to drive the turbines. The cooled water returns to the reactor to begin a new cycle.

For practical and economic reasons, more than one of these coolant loops are used. In the PWR plant at Shippingport, Pa., for instance, four are used with a single reactor. Each loop has a separate heat exchanger and pump, and its own pressure-, temperature-, and flow-measuring instruments. Normally, only three or less of the coolant loops operate at once.

It is very important that no steam be produced inside the reactor, because the coolant water moderates the speed of neutrons moving between the fuel elements. (Compared to water, steam has practically no moderating effect.) On the other hand, it is necessary for plant efficiency to maintain the coolant temperature as

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ENGINEERING NEWS

SOLVE SPACE AND WIRING PROBLEMS with Switch/Light Combinations

You probably use these Hetherington Switch/Light combinations every time you travel via leading air lines. Here they are used as hostess call lights. As you may have suspected, however, this is just the beginning of their usefulness—both in aircraft as well as in commercial instrumentation and control uses. Their unique combination of single- or double-pole switching action together with an illuminating push button offers definite advantages in terms of greatly reduced panel space and the elimination of switch-to-light wiring. Usually the entire assembly takes no more space than a conventional switch alone.

Of particular importance for many applications, Hetherington Switch/Light combinations make it easier for operators to keep closer tabs on crowded panels without confusing control functions. By connecting the light to an externally controlled circuit the illuminated button virtually cries, *"Push Me,"* to attract the operator's attention at the right time. In other models, lamp circuits are controlled by the main switch contacts or by a second set of auxiliary contacts.

Typical contact ratings are 15 amps at 30 volts ac-dc. Illuminated buttons can be made in virtually any color, shape or size.

HERE'S EXTRA SAFETY FOR WARNING LIGHT APPLICATIONS

JUST "PRESS TO TEST"

Ever wonder whether a warning light for a critical circuit was merely OFF or whether the bulb was burned-out?

If so, you'll appreciate the "Press-to-Test" feature of this tiny Hetherington Type L3200 light.

The lamp and its circuit can be "checked-out" simply by pressing on the spring-mounted plastic lens cap. This makes contact through a separate third terminal circuit. When cap is released, the lamp functions through the regular circuit.

The long plastic lens of the L3200 gives wide, 180-degree visibility with either standard or edge-lit panels. Uses AN3140 lamps. For more details, write for Bulletin L-2b.

BETTER SWITCHES FOR BETTER APPLIANCES

A good electrical product deserves a good switch—and for types in the 5 to 50 ampere range that means Hetherington. Sturdy, good-looking switches —both push button, toggle, rotary, and other types—for unique operating or mounting requirements have long been a Hetherington specialty. Chances are, Hetherington switch engineers can recommend something out-of-the-ordinary that will enhance the appearance and saleability of your electrical products while assuring long, happy switch performance.

NEW PUSH BUTTON SWITCHES FOR AVIATION'S TOUGHEST JOBS . . . *Designed to MIL-S-6743 Specs*

Designed to MIL-S-6743 drawing MS25089, these rugged, fully moisture-proofed snap action switches take a full 50 G shock and wide-amplitude vibrations up to 55 cps without contact transfer.

The basic switch can be fitted with any of eight different anodized aluminum mounting adapters, such as those illustrated, to meet virtually any mounting or design requirement.

Two-circuit, three-terminal, SPDT, and other contact arrangements are available with ratings up to 10 amps, 28 volts dc. Ask for details on Hetherington Series W100.

Similar switches for non-MIL and industrial applications are available in over 1800 different types as Hetherington Series "JR."

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designed for use where one failure is one too many

high as the pressure will permit without boiling.

In each coolant loop, high-speed resistance bulbs measure inlet and outlet temperatures at the reactor. Indicating receivers driven by magnetic amplifiers indicate the temperature prevailing at these eight points and provide retransmission elements for recording and control.

Average coolant temperature is an important parameter in reactor control: one of its direct functions is the rate of heat transfer to the steam power plant. In a multiple-coolant-loop plant, such as a PWR, it is necessary that the average temperature be obtained, not from the average of all of the inlet and outlet temperatures but from the average of the highest inlet temperature and highest outlet temperature. This is done to make sure that variations in flow and incomplete mixing in the reactor do not produce a higher temperature in the reactor than the average indicates.

Designing a device to select the highest inlet and outlet temperatures and retransmitting these values to an averaging indicator and controller suggests the situation in which the highest bidder wins; therefore it is called "auctioneering". (Nucleonics terminology is traditionally whimsical.)

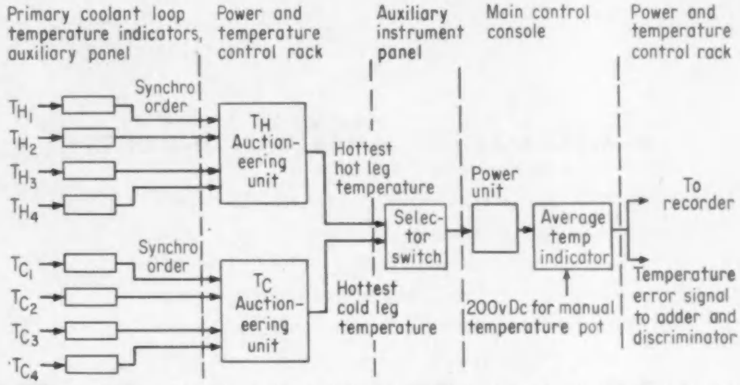


FIG. 1—Two "auctioneering units" find the hottest of the hot outlet temperatures and the the hottest of the cold inlet temperatures, respectively. The average of these is compared to a set-point (manual temperature pot) to get control error signal.

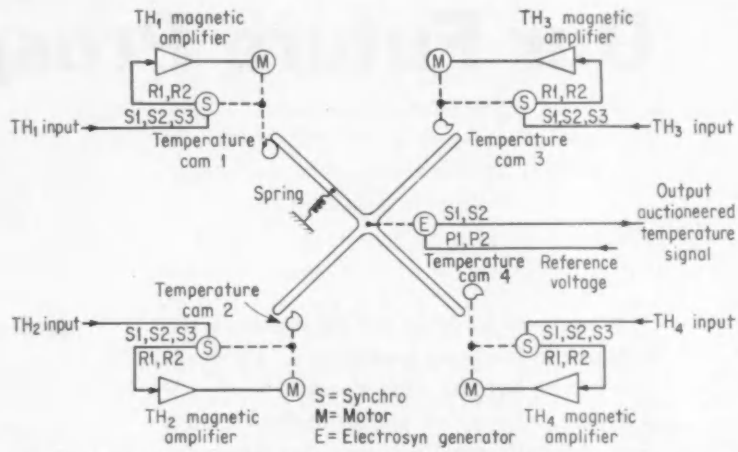


FIG. 2. In auctioneering unit, a microsyn generator produces an output signal proportional to the highest of four input temperatures. The microsyn is positioned by a spring-loaded four-arm cam follower that rides on highest cam. Cams are servoed to input temperature.

The "auctioneering" units

Two auctioneering units (see Figure 1) are required per control system. As shown, they provide two electrical signals, one proportional to the hottest of the four hot-leg coolant temperatures and one proportional to the hottest of the four cold-leg temperatures. These two voltages are used to compute the "average" of the highest hot-leg and the highest of the cold-leg temperatures as indicated on the "average temperage indicator". The average temperature signal is then compared with a manual preset temperature to provide the temperature error signal that eventually controls the position of the reactor rods.

Functionally, both auctioneering units are identical, the only difference being the switch nomenclature on the front panels. In operation, each unit receives four temperature synchro signals from the primary coolant temperature indicators located on the auxiliary instrument panel of the PWR system. The T_H unit receives the hot-leg temperature signals and the T_c unit receives the cold-leg signals. The four temperature signals are "auctioneered" for the highest temperature by four servo-driven temperature cams and a cam follower assembly, which produce a single electrical output proportional to the auctioneered temperature.

Four switches on the front panel cut out any one or all of the temperature servos and any unused temperature channels.

Figure 2 is a schematic of the auctioneering unit showing the electrical circuitry and the mechanical configuration. Each servo loop receives a temperature synchro signal (*S*1, *S*2, *S*3) from a retransmission synchro located in the primary coolant loop temperature indicators. The rotor signals (*R*1 and *R*2) proportional to the position errors of the receiving synchro control transformers are fed to their respective magnetic amplifiers and amplified to drive the servomotors.

Each servomotor positions a temperature cam, and each cam corresponds to the particular value of the input temperature signal received.

To "auctioneer" the temperature signal, a four-arm cam-follower assembly senses the angular motion of the four cams in such a way that the follower's own angular motion is always proportional to the highest cam position. An ElectroSyn generator (microsyn) is coupled one-to-one to the cam-follower axis to produce an electrical signal proportional to the auctioneered temperature.

Four switch-actuating cams incorporated with the four temperature cams trip four SPDT electrical limit switches. These switches work in conjunction with four "IN" and "OUT" switches located on the front panel. When one or more of these switches are placed in the "OUT" position, the control phase of the respective servomotor is connected to the reference-line voltage so that the motor drives the temperature cam to its low (cam-rise) position. At the minimum cam rise point, the switch cam actuates its limit switch and short circuits the control winding of the servomotor, thus stopping the motor. Conversely, when an "IN-OUT" switch is thrown to the "IN" position, the control winding of the affected servomotor is connected to the amplifier output and the motor drives in normal fashion.

How Research Shapes Our Future Prosperity

If you are looking for an industry that is going to keep on booming in 1958 and every year for the next decade, here it is. It is the industry of technological innovation through research and development.

Last year this great new industry spent over $7 billion to discover and develop new industrial products, processes and equipment. This year the preliminary McGraw-Hill survey indicates that total expenditures for industrial research and development will be even greater, perhaps as much as $8 billion. Of the companies surveyed, 57% plan to spend as much as in 1957 and 38% plan to spend more.

The sustained expansion in research and development is the best guarantee we have that the current decline in business investment in new plants and equipment will be relatively short-lived. There can be no prolonged decline in investment in an economy where technology is changing rapidly.

This editorial is designed to show how the continued surge in research and development can be expected to lead first to new products, and eventually to renewed expansion of investment in new industrial plants and equipment. Such expansion is the essence of national economic growth.

A Slow Start

The impact of research on sales and investment is still very gradual. Research spending itself has more than doubled in the last four years. But only 32% of all manufacturing firms report significant capital outlays to make new products. We are not reaping the full dividends of industrial research as yet for several reasons:

- Research expenditures were relatively small until the Korean War of 1950 brought substantial government contracts in aviation, electronic and related fields. Heavy research outlays for civilian and industrial products came even later.
- There is an average *lag,* according to research directors consulted by the McGraw-Hill Department of Economics, of roughly seven years from the start of research until the product is ready for large scale output — about five years of research and at least two years to solve production problems and develop markets.
- Complex products, such as new consumer durables and industrial machinery, have an even longer time lag.

However, new developments are certainly underway. Research began to increase in all lines of business when Korean War restrictions and

the excess profits tax came to an end in 1953. The tax revision of 1954 added a new incentive by making research outlays deductible as a current business expense. By 1955, the research boom was on.

When Is The Payoff?

With a lag of about seven years, it will be the early 1960s before these new developments become a dominant factor in capital investment. But once the flow of new products and new processes starts, it will accelerate sharply — just as research spending has accelerated in the past few years.

By 1960, over $50 billion in sales will be coming from products not on the market as recently as 1956. Sales of new products will increase year by year, but they will gain most in 1960-1962, or five years after the recent spurt in research expenditures.

Capital expenditures to manufacture new products will also rise, but with a slightly longer lag. Here the sharpest rise should come in 1962-1965, as the new products reach a volume that calls for a significant amount of new capacity. In most cases, initial output of new products will come from existing capacity.

This timing of a new wave in capital investment appears logical on other grounds. Population experts forecast an upsurge in marriages and births around 1965. So by 1962, industry will be starting to tool up for new mass markets.

The important point is this: As we approach the 1960s more and more sales and investment will be in new products growing out of research. By 1960 well over 10% of manufacturing sales will be in new products not on the market in 1956.

Meanwhile — research will help stabilize capital spending by raising the level of modernization and replacement expenditures. Of course, research does not eliminate all the ups and downs in the demand for capital goods, for there remain variations in the amount spent to expand capacity. But a high level of modernization, to cut costs and improve quality, does put a floor under any drop in investment.

What To Expect

During the next few years we can expect an increasing flow of new materials, new metallic alloys, new machinery — primarily those developments coming out of long-established research programs in the chemical and electrical industries. Industry will make wider use of specialized computers and automated equipment.

But the dramatic payoff on research comes even later. In the early 1960s the consumer goods industries will begin tooling up for their really new products — things so basically new they can change the way a family lives. Such items as plastic houses, paper apparel, turbine autos are under development right now. But it will take several years to get costs down and for population and incomes to grow to the point where mass markets are created.

When we reach that point in the mid-1960s, there will begin the greatest surge of capital investment in all history. And then — around 1965 — the new processes (full automation, atomic power, continuous steel casting) which are the slowest and most expensive part of the research chain to develop, will come into play.

The combined impact of new products and new processes, to meet an expanding market, will thus be felt in the mid-1960s — eight to ten years after the recent sharp increase in research spending. The full impact is that far away because of the lags for applied research, pilot plant studies and market introduction. But to a large degree the prosperity of the 1960s has already been shaped by the research programs now underway.

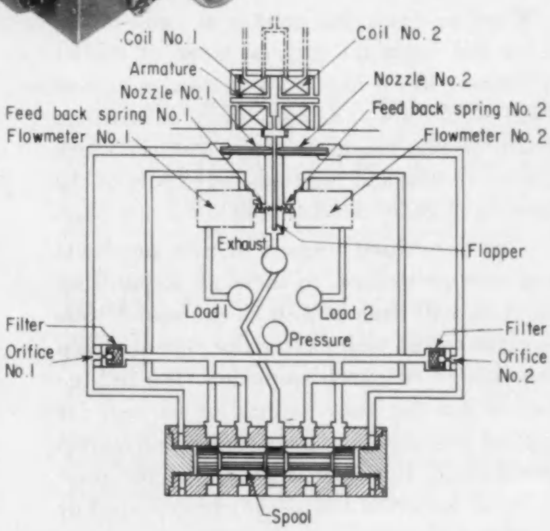
This message is one of a series prepared by the McGraw-Hill Department of Economics to help increase public knowledge and understanding of important nation-wide developments. Permission is freely extended to newspapers, groups or individuals to quote or reprint all or parts of the text.

Donald C McGraw
PRESIDENT

McGRAW-HILL PUBLISHING COMPANY, INC.

NEW PRODUCTS

LISTING IN GROUPS



SERVOVALVE weighs only 11 oz.

Designed for aircraft and missile servo systems, this lightweight electrohydraulic servovalve features fast response, low internal friction, minimum null shift, and faithful reproduction of small input signals. Versions are available for rated flow capacities at from ½ to 7 gpm at plus or minus 8.0 ma input, and for any system pressure of over 500 psi. Dimensions are 2½ by 2¼ by 2¾ in. and weight is approximately 11 oz. Operating ambient temperatures range from minus 65 to plus 450 deg F.

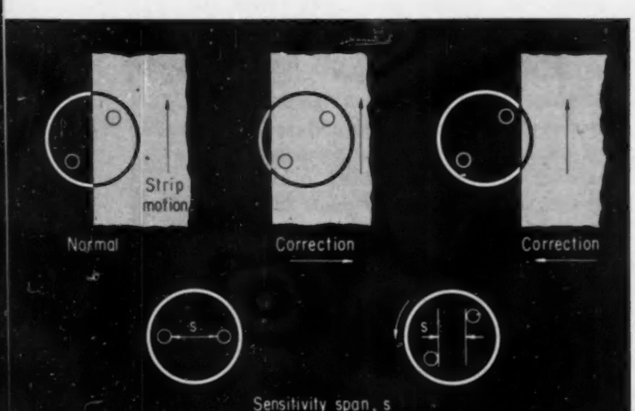
The valve operates on a dynamic continuous-flow-sensing principle, and consists of a dry-coil torque motor, hydraulically balanced flapper-type pilot valve, four-way slide-type power valve, and a flowmeter feedback loop. Schematic below the photo illustrates the internal arrangement.

An electrical input signal introduced in the coils causes them to position the flapper so as to increase the pressure at one of the pilot nozzles. This produces a pressure unbalance that displaces the spool of the power-stage valve.

Movement of the power spool produces flow through the load ports. Flow from the load through the flowmeter exerts a force proportional to the rate of flow. This acts on the flapper and counterbalances its prior displacement. When the flapper centers, the power spool is held in hydraulic balance and movement is stopped at an equilibrium position. Output flow at this point is directly proportional to the amplitude of the input signal.

The flow-type feedback control permits relatively large power spool overlap, hence large spool clearances. According to the manufacturer, this design not only reduces production costs but also minimizes dead zone.—Pesco Products Div., Borg-Warner Corp., Bedford, Ohio.

Circle No. 1 on reply card



EDGE GUIDE provides close control.

Already in use on a tantalum slitting machine, the Edgetron edge-control system consists primarily of two photoelectric cells mounted in a sensing head, a control box to receive and relay signals, and a correction device. The accompanying schematic illustrates the action of the sensing head. One of the light beams is normally interrupted; displacement of the moving strip to the left interrupts both beams, displacement to the right exposes them. In either case, the correction device moves the strip in the opposite direction. The sketch also shows how the control span is varied by simply rotating the sensing head to change the lateral distance between beams. This simple arrangement permits edge control to within 0.005 in. where desired.—Intercontinental Dynamics Corp., Englewood, N. J.

Circle No. 2 on reply card

PNEUMATIC RELAY solves equations.

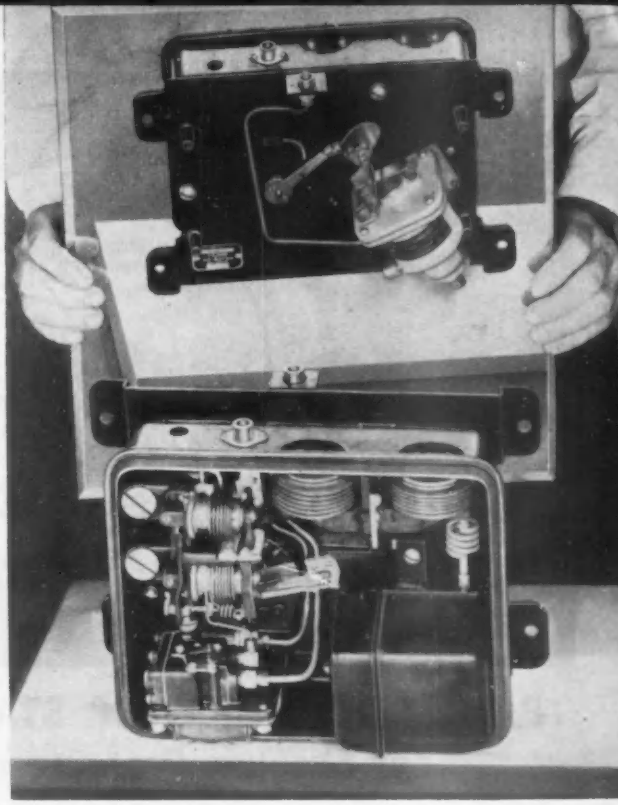
This pneumatic relay solves equations continuously by combining two or more pneumatic signals in varying, predetermined proportions. The device multiplies or divides one pneumatic signal, representing a measured variable, by some predetermined function of a second variable. It also adds and subtracts signals and provides proportional control action. Applications include temperature and pressure compensation, and the remote adjustment of proportional band in single or multi-element pneumatic control systems.

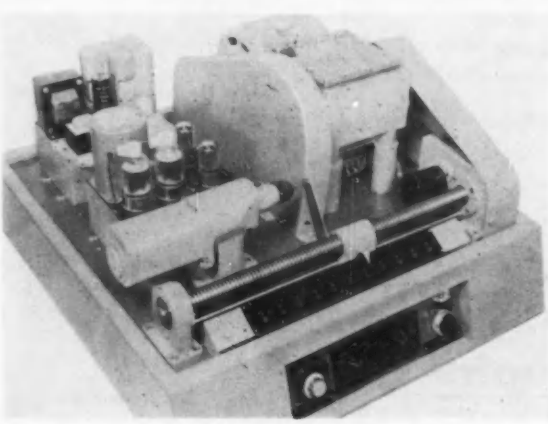
Called a computing relay, the unit uses standard SAMA signal ranges of 3-27 and 3-15 psig, requires a 30- or 18-psig air supply. Both direct- and reverse-acting models are available.

With a 30-psig supply balanced at 15 psig, the relay has an output capacity of 2.0 scfm. A remote adjuster, also available, has an output capacity of 0.6 scfm when the transmitted signal is dropped 1 psig. At balance on dead-end service, it consumes 0.10 scfm air. Under the same conditions, the remote adjuster uses only 0.06 scfm.

Photo right, a front view and mirror image of the back of a typical unit, shows how the second signal is supplied through a pneumatic receiver and either a calibrated cam or linkage mechanism. Units with the linkage mechanism have a somewhat wider proportional band range.—Bailey Meter Co., Cleveland, O.

Circle No. 3 on reply card





CONTROL SYSTEMS for ¼ to 100 hp.

A new line of electromechanical control systems features improved dynamic response, high accuracy, and guaranteed repeatability. Originally designed for tracer lathe control, the systems can serve a wide variety of applications requiring power outputs from ¼ to 100 hp. Components include an electrical or mechanical signal comparator, a power-supply converter, an electronic amplifier, and a unique mechanical power amplifier (see page 113). Photo right shows a typical demonstration unit.

Simplified design and the absence of critical assemblies or adjustments minimize maintenance; plug-in components facilitate replacement.—Seneca Falls Machine Co., Seneca Falls, N. Y.

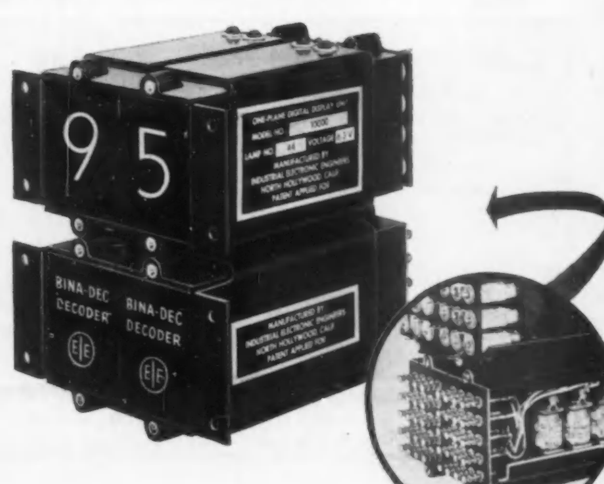
Circle No. 4 on reply card

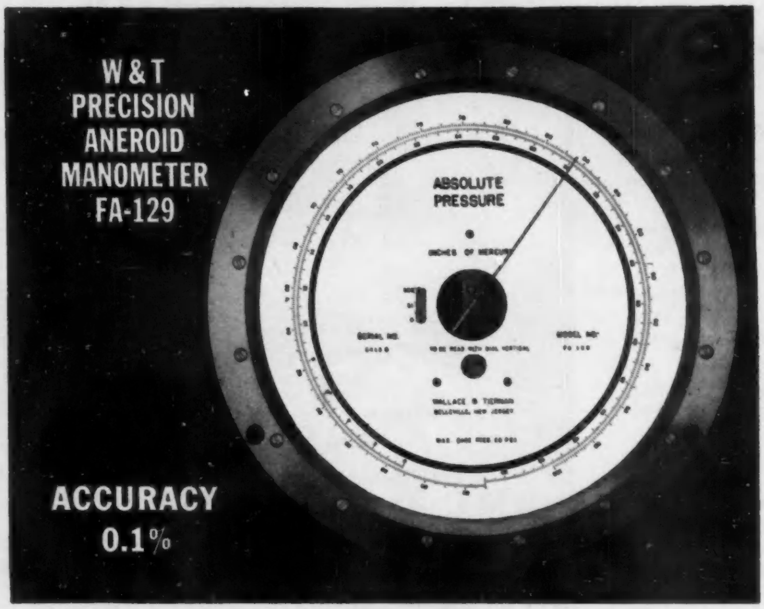
NEW DECODER uses relay tree.

This new Bina-Dec binary-to-decimal decoding unit has been designed primarily for electronic digital display equipment. Areas of application include missile ground test equipment, counting circuitry, computers, and controls. Modular construction permits assembly of as many decades as required. The number of relay trees for the translation depends on the code used. Four or five terminals plus a common terminal provide input information to control the relays; 10 terminals plus a common, the outgoing decimal information. Lockup contacts maintain settings in pulse-type operation.

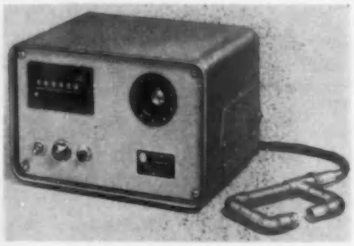
Decimal-coded-binary codes that may be translated include four-bit codes, the two-out-of-five code, and the excess-3 code. Others are available on special request.—Industrial Electronic Engineers, North Hollywood, Calif.

Circle No. 5 on reply card





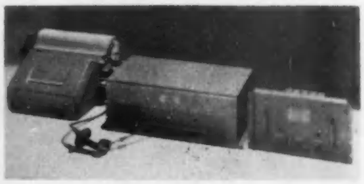
DATA HANDLING & DISPLAY



TO 30,000 COUNTS PER MIN

The Model N-1 Count-Pak uses a compact, glow-transfer, cold-cathode counting tube, and a high-speed magnetic counter combined with a small, adaptable photo-head. Unit operates at speeds up to 30,000 counts per min for more than one billion counts. Its photo-head can be made to handle a variety of applications. Use of transistors and printed circuits reduces heating and simplifies wiring.—Veeder-Root, Inc., Hartford, Conn.

Circle No. 6 on reply card



ENCODER SYSTEMS

The new LE-100 linear encoder systems measure and accurately record linear lengths from 0 to 100 ft in ⅛-in., 1/16-in., or 0.001-in. increments. Accuracy is within plus or minus one count of the least significant digit.—G. M. Giannini & Co., Monrovia, Calif.

Circle No. 7 on reply card

NO CONTACT BOUNCE

A new commutator designed primarily for pam-fm-fm telemetering systems will not introduce false synchronization signals because it has no contact bounce. In operation, all signals are initiated and concluded by the opening of contacts. Other advantages claimed for the new device:

• photo-etched construction that per-

air circuitry:

a new term of importance to control engineers.

Air has come of age as a control medium. No longer is it confined to the simple jobs of pushing a clamping device, moving a lever, or blowing chips. No longer is an air circuit just a valve, reservoir, and cylinder. Today the most complex of industrial control problems can and are being solved efficiently with air.

Today, pneumatic circuits can be interconnected. They can be set to control a complex sequence of operations *automatically*. They can be combined with electrical circuits. There is *no* control problem you have that can't be solved successfully with air.

The new role that pneumatic control can play in industrial operations demands a new way of thinking about air control. It demands a new way to describe control by air—a new name that suggests some of its limitless control possibilities. That's why Westinghouse Air Brake Company is now using the term "air circuitry" to describe the application of air control to automation.

Westinghouse Air Circuitry, we realize, has to be more than *just as good* as your present means of control. It has to offer you *extra advantages*. And it does.

Chief among these is its extreme simplicity. The devices themselves are uncomplicated mechanical devices. They have few moving parts. They are easy to service by any mechanic. The circuit connections are made with pipe—and what could be simpler than that!

This extreme simplicity brings with it other important "pluses" for air circuitry. The simple equipment is unusually reliable—there are few moving parts to wear out or get out of adjustment. The devices are sturdy and durable. They require very little maintenance. What maintenance there is can be handled without the services of highly trained technicians.

Above all, remember: no means of control is as *safe* as air.

Air circuitry can help you simplify your control problems. It can help you get accurate answers to your automation problems on any industrial machine . . . in any industrial process. And Westinghouse Air Brake Company can help you with the engineering of a suitable system. Westinghouse has been in the control engineering business for 80 years now. It has been at the forefront of the development and improvement of air control equipment and its applications.

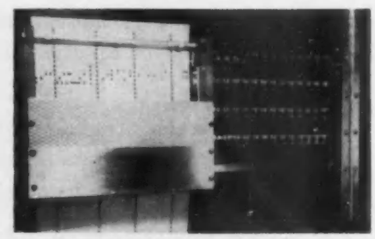
For more information on Westinghouse Air Circuitry—how it has helped other companies, how it can help you—write for your copy of "Basic Pneumatic Control," or call our nearest sales office.

WESTINGHOUSE AIR BRAKE COMPANY, INDUSTRIAL PRODUCTS DIVISION, WILMERDING, PA.

mits simple alteration of the number of contracts and well time
- size reduction without expensive machining
- elimination of the customary second gating deck
- elimination of electronic gating
- reduction of overall system costs

Unit measures 4 in. in diam by 1½ in. in length, exclusive of motor, has 30 single-pole contacts, and speeds of 10, 5, and 2½ rps on order. It draws less than 100 ma at 117 volts, 400 cps, single-phase.—Genisco, Inc., Los Angeles, Calif.

Circle No. 8 on reply card



LOW-COST TAPE READER

Designed for a broad range of control and programming applications, this new perforated tape and card reader accommodates widths from 3 to 18 in. with 10 circuits per in. Two types of tape-advance mechanisms are available: a silent motor-driven sprocket and a solenoid and pawl arrangement. The latter has a maximum tape speed of 10 rows per sec.—Program Control Associates, New York.

Circle No. 9 on reply card

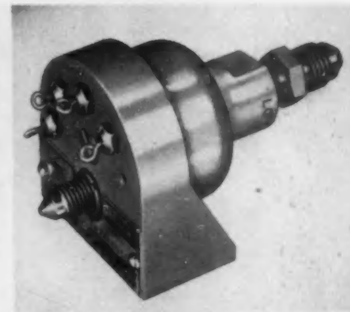
PLUS. . . . .

(10) A line of simple flow indicators for use in circulating water or oil lines is available from **McIntosh Equipment Corp.**, New York. . . . (11) **Navigation Computer Corp.**, Philadelphia, Pa., offers a new **reversible binary counter** for use in digital control of machine tools. . . . (12) A new **electronic proportioning temperature controller,** now being produced by **Electronic Processes Corp. of California,** San Francisco, Calif., features independent control and plug-in circuits. . . . (13) **Panellit, Inc.,** Skokie, Ill., has developed a new **recording annunciator** that monitors eight to 32 points per operational system.

Circle 10, 11, 12, or 13 on reply card

NEW PRODUCTS

PRIMARY ELEMENTS & TRANSDUCER



HIGH-RESOLUTION

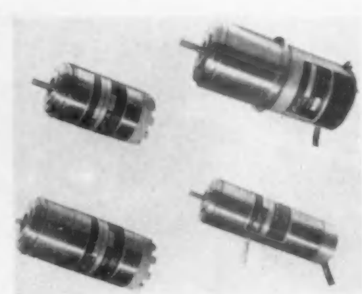
Covering pressure ranges from 200 to 10,000 psi, this lightweight, bourdon-tube pressure transducer should prove particularly useful in measuring the pressure of noncorrosive liquids or gases in airborne applications. Center mounting of the bourdon tube lowers hysteresis and assures excellent performance under severe vibration.

Characteristics:

Resolution: up to 400 wires
Vibration: 25 g's to 2,000 cps
Resistance: 3 to 16 k
Weight: 6 oz for ranges to 2,000 psi, 12 oz for ranges from 2,000 to 10,000 psi

—G. M. Giannini & Co., Pasadena, Calif.

Circle No. 14 on reply card

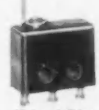


PRECISION TACHOMETERS

Now in production, this new line of servomotor tachometers suits integration applications that require accuracies within 0.01 percent. Sizes range from 11 to 20 (1.062 to 1.950 in. diam). Features include high linearity output voltage, good temperature stability, and very low harmonic distor-

MICRO SWITCH Precision Switches

NEW



Actual Size

We've Miniaturized the Subminiature!

WEIGHT: *1 gram... 28 switches to the ounce... over 430 to the pound.* SIZE: *.500" long, .200" wide, .350" high.*
CUBIC CONTENT: *.035 cubic inches.* ELECTRICAL RATING: *5 amps-250 vac, 30 vdc. SPDT.*

After a long period of laboratory development, MICRO SWITCH announces this new, highly miniaturized precision snap-action switch and a complementary line of actuators.

We call it the "Sub-subminiature!"

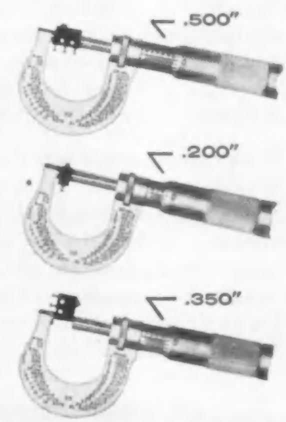
This new "SX" basic switch represents an entirely new set of answers to the space-weight problems in dependable precision switching. It combines new small size with more than ample capacity for wide usefulness, meeting the pressing demand for miniaturization combined with reliability.

In its exacting development, many problems of design, testing and quality control presented themselves. However, 23 years of experience proved of immense value. As a result, a new standard has thus been set by which all precision switches must be measured.

This broad experience can prove of equal value to you. Send for more information about this new switch. Request Data Sheet No. 148.

—•—

MICRO SWITCH...FREEPORT, ILL.
A division of Honeywell
In Canada: Honeywell Controls, Ltd., Toronto 17, Ontario



Honeywell
MICRO SWITCH PRECISION SWITCHES

The two-word name MICRO SWITCH is NOT a generic term. It is the name of a division of Honeywell.

tion. Units are temperature controlled or temperature compensated.—Kearfott Co., Inc., Clifton, N. J.

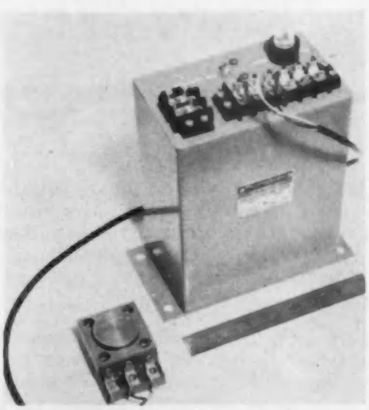
Circle No. 15 on reply card

PLUS. . . . .

(16) **Farmer Electric Products Co., Inc.,** Newton Lower Falls, Mass., is offering a pair of **miniature photoelectric heads** for direct- or reflected-light applications. . . . (17) **G. M. Giannini & Co., Inc.,** Pasadena, Calif., has another new **bourdon-tube pressure transducer** for ranges of 0-100 to 0-6,000 psi, **differential** or gage. . . . (18) Thermocouples, connection heads, wells, fittings, and mounting attachments are the components found in a new expanded line of **thermocouple assemblies** available from **Thermo Electric Co., Inc.,** Saddle Brook, N. J. . . . (19) **Westinghouse Electric Corp.,** Pittsburgh, Pa., recently demonstrated a new **radiation detector** for high-intensity atomic particles.

Circle No. 16, 17, 18, or 19 on reply card

CONTROLLERS, SWITCHES & RELAYS



NEW PROXIMITY SWITCH

Absence of moving parts makes the operating life of this new proximity limit switch totally independent of the number of switching operations. The unit consists of two parts: a sensing element, containing an open C core and two windings, all forming a variable-reluctance bridge circuit; and a control element containing a balance circuit, amplifier, phase detector,

precision flip-flop circuit, transistor output amplifier, and power supply. Electrical output, 24 vdc at 0.335 amp, will drive Cypak and other static control elements, as well as 24-volt dc relays and solenoids. – Westinghouse Electric Corp., Pittsburgh, Pa.

Circle No. 20 on reply card

POLARIZED RELAYS

A new line of high-speed polarized relays provides fast action without contact bounce and will, under some conditions, handle over 1,000 pulses per sec.

Characteristics:

Contact arrangement: spdt, with two independent coils
Coil resistance: up to 5,000 ohms per coil
Contact ratings: 120 vac or dc, 60 ma to 2 amp, depending on speed desired
–Hart Mfg. Co., Hartford, Conn.

Circle No. 21 on reply card

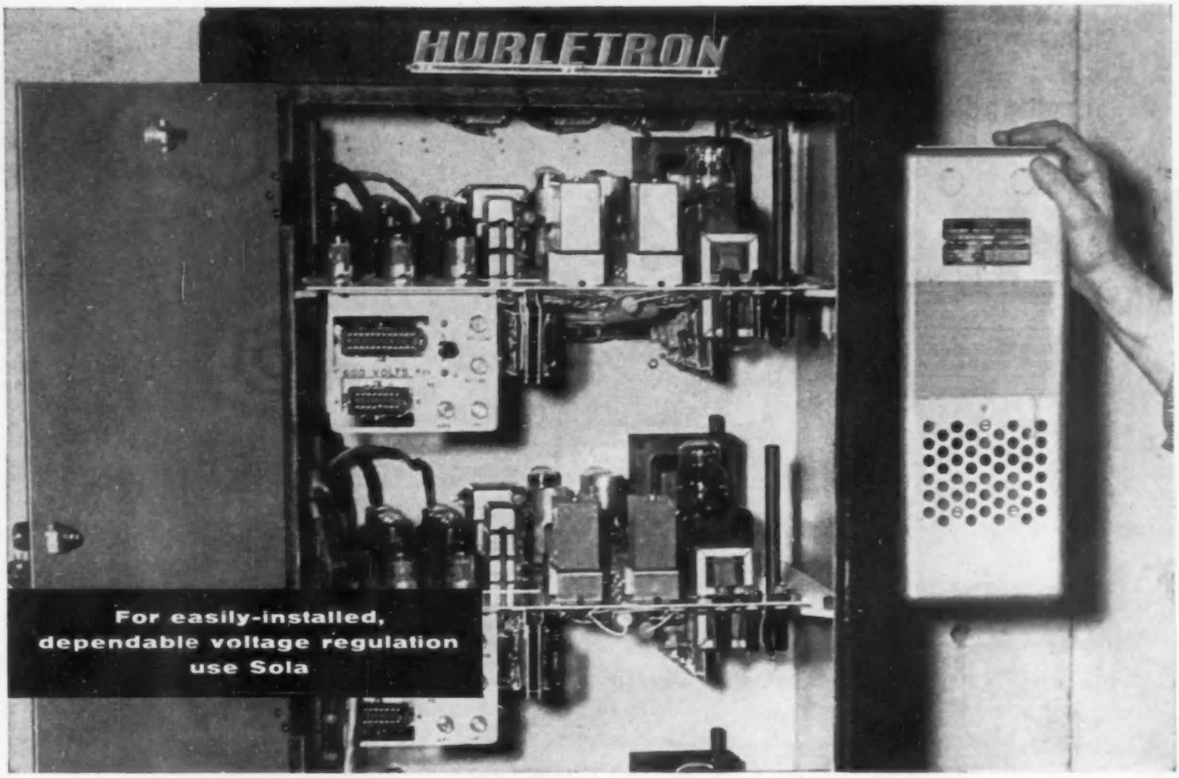
FOR MACHINE TOOLS

Three new synchronous-motor-driven timers provide maximum ranges of 1, 3 and 5 min. Each is adjustable in increments equal to 1/60 of the full range. A bronze pointer, depressed and rotated to any desired position on the indicating dial, sets the timer. All motors operate on a 110-volt, 60-cycle supply. For a higher voltage service, a control transformer and terminal block can be added.–Cutler-Hammer Inc., Milwaukee, Wis.

Circle No. 22 on reply card

HIGH ACCURACY P-D METER

A British firm has developed a new positive-displacement meter accurate to within 0.03 percent. Essentially, it is a free piston operating in a cylinder of known swept volume. A double-L-

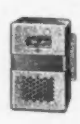


FIVE constant voltage transformer types answer most stabilizing needs

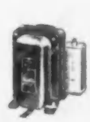
1 **Standard Sola Constant Voltage Transformers** can be built into your equipment, or added as an accessory. Either way it's simple, and economical of space and money to do it with a Sola. For example, Electric Eye Equipment Company uses it as a standard accessory on their Hurletron, automatic, proportional printing register control. The transformer is pictured above, mounted to the right of the control cabinet.

The Sola Constant Voltage Transformer stabilizes output voltage within ±1% regardless of input voltage variations up to ±15%. Response is within 1.5 cycles. It is a static-magnetic regulator . . . has no tubes or moving parts; requires no manual adjustments, or maintenance.

2 **Harmonic-Free***: Output voltage wave has less than 3% total rms harmonic content . . . other features identical with standard type . . . automatic, continuous regulation . . . for rectifiers and other loads sensitive to harmonics . . . low external field.

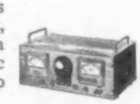


3 **Plate-Filament***: Regulation is ±3% with line input between 100-130v . . . plate and filament windings are combined on a single, compact core for chassis mounting . . . good isolation of input and output circuits . . . automatic, static-magnetic regulation.



4 **Filament***: Regulation ±1% with input voltage fluctuations up to ±15% . . . 6.3v output for large numbers of electron tubes . . . current-limiting action minimizes cold inrush currents, also protects against damage from load faults . . . 75-80% efficiency.

5 **Adjustable, Harmonic-Free:** Provides output adjustable from 0-130 volts, ac, . . . regulates within ±1% with less than 3% total rms harmonic content . . . portable for lab or shop use . . . or mounts on rack.



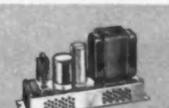
*Available from stock or custom-designed.

For complete data write for Bulletin 26G-CV-170

Sola Electric Co., 4633 W. 16th St., Chicago 50, Ill., Bishop 2-1414 • Offices in Principal cities • In Canada, Sola Electric (Canada) Ltd., 24 Canmotor Ave., Toronto 14, Ont.

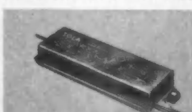
SOLA

CONSTANT VOLTAGE TRANSFORMERS



REGULATED DC POWER SUPPLIES

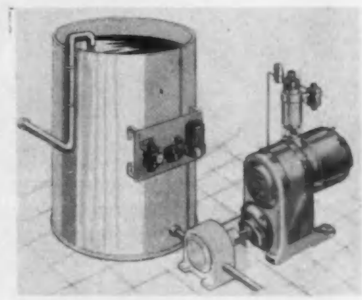
MERCURY LAMP TRANSFORMERS



FLUORESCENT LAMP BALLASTS

port valve diverts the liquid input alternately to opposite ends of the cylinder, where proximity switches initiate signals that operate solenoid air valves. These control an air cylinder which strokes the L-port valve. As a rate-of-flow controller, the meter operates at a stroke frequency determined by an adjustable timer. As a preset meter, it operates at a fixed-stroke frequency.—Dunford & Elliott, Ltd., Sheffield, England.

Circle No. 23 on reply card



LEVEL CONTROL SYSTEM

Drawing above illustrates the principal components of a new liquid-level control system. Basically, the system consists of a Varidrive motor equipped with a pneumatic Varitrol actuator. The latter, receiving a signal from an air- or liquid-purge level controller, regulates the motor speed. In this way the pump maintains a constant level in the tank. Entirely pneumatic, the system contains no floats or flow restricting valves.—U. S. Electrical Motors, Inc., Los Angeles, Calif.

Circle No. 24 on reply card

PLUS. . . . .

(25) A low-noise, low-level **data-sampling switch,** manufactured by **Genisco, Inc.,** Los Angeles, Calif., operates by successively depressing metal reeds against a common ring. . . . (26) **National Time & Signal Corp.,** Detroit, Mich., has developed a line of **rotary switch assemblies** with from four to 60 cam-operated contacts. . . . (27) For applications requiring on-off switch-type control, the **Magnetic Controls Co.,** Minneapolis, Minn., offers the Model SA-6A-1 **magnetic switching amplifier.** . . . (28) **Revere Corp. of America,** Wallingford, Conn., announces a new **level indicator** that operates on a photoelectric principle.

Circle No. 25, 26, 27 or 28 on reply card

Bailey Recorder is key to "step-by-step" automation

When you are pioneering a new process and don't know all the answers, complete automation is seldom practical. The first step is to identify your variables and measure them. Nothing does this job better than a Bailey Recorder. One instrument can record any four variables that can be converted to electric *or* pneumatic signals.

Once you get a better understanding of the variables in your process, you will want to add controls and feed back your measurements. Here's where the versatility of the Bailey Recorder comes into play. For the same Bailey instrument you use to record variables is designed to accommodate plug-in control units.

When you use a Bailey Recorder, you can build your instrumentation along with your process. At the start, you use only the plug-in units for recording. Then you add plug-in controls as you see the need for them.

For the complete story of how you can use a Bailey Recorder for step-by-step automation, see your Bailey Engineer.

G-42-1

Instruments and controls for power and process

BAILEY METER COMPANY

1079 IVANHOE ROAD • CLEVELAND 10, OHIO

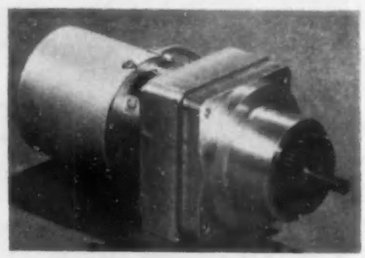
In Canada—Bailey Meter Company Limited, Montreal

POWER SUPPLIES

GROUND POWER SYSTEM

Designed for automatic prelaunch checkout of missile systems, this 15-kva motor-clutch-generator set provides 400-cycle frequency regulation of 0.1 percent. A tuning-fork speed control regulates an electromagnetic clutch between a 60-cps induction drive motor and the 400-cps generator. Voltage regulation is within 1 percent and the efficiency at 15 kva is 60 percent.—Varo Mfg. Co., Garland, Tex.

Circle No. 29 on reply card



CONSTANT-SPEED DRIVE

Pictured is a new constant-speed power drive designed for computer and control system applications. The unit will deliver 16 oz-in. of torque at a constant speed of 1,000 rpm. Output speed is held to within 0.1 percent with an input voltage variation of 20 percent and an input speed of 1,100 rpm, plus or minus 15 percent. Typical unit measures 4¼ in. by 2 in. by 2 in. and weighs about 1 lb. Its timing motor draws 3 watts at 28 vdc.—M. Ten Bosch, Inc., Pleasantville, N. Y.

Circle No. 30 on reply card

MAGAMP CONTROLLED

A new regulated dc power supply with silicon rectifiers features magnetic amplifier control and a ferromagnetic

overload protection circuit. This design completely eliminates the one-time fusing normally associated with silicon units.

Characteristics:

Input: 115 vac, 60 cycle
Output: 5-30 vdc, 40 amp
Regulation: within 0.5 percent
Ripple: 1 percent
–Gates Electronic Co., New York.

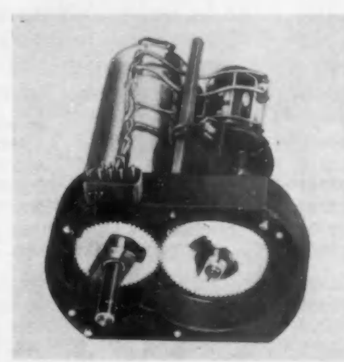
Circle No. 31 on reply card

PLUS. . . . .

(32) **United Electrodynamics,** Pasadena, Calif., has added to its line of modular components a **transistorized dual dc voltage regulator** for missile and airborne telemetry. . . . (33) The **REL-203 Power Supply,** designed by **Rheem Mfg. Co.,** Rivera, Calif., uses an r-f filter to protect radio equipment from interference. . . . (34) **Dressen-Barnes Corp.,** Pasadena, Calif., is now marketing a **multiplier phototube power supply** with an output of 800 to 2,000 vdc at 0 to 25 ma.

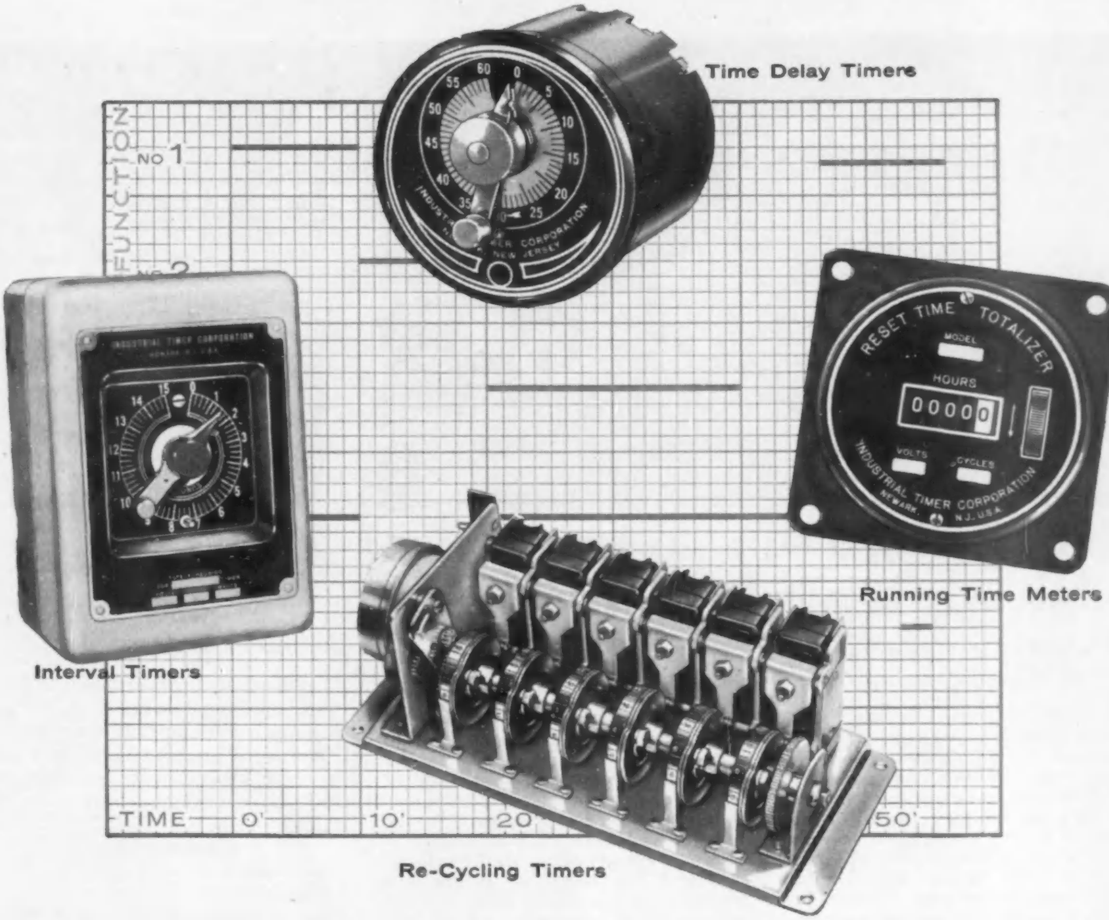
Circle No. 32, 33, or 34 on reply card

ACTUATORS & FINAL CONTROL ELEMENTS



ROTARY ACTUATOR

This new rotary actuator shown with front plate and back cover removed, uses a small, high-torque motor coupled through anti-backlash gears to a limit switch and potentiometer drive. Standard models operate at ¼ to 150 rpm, and produce up to 150 lb-in. of torque in from 3 to 30 turns. Motor provides high acceleration and, with proper external circuit, dynamic braking. Potentiometer may be used to



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You'll get quick deliveries from Industrial Timer

If slow deliveries of timers have been delaying you in your automatic control projects, try us! True, your problem may be different and difficult indeed, for no two automatic control jobs are exactly alike. But our record in helping out in situations like these is excellent. For in this field we have a valuable background, twenty years of timer experience to be exact, that has provided us with the special knowledge required to supply our customers with the right answers.

How do we do it? The answer is in what we believe to be the largest variety of standard and combination timer units anywhere in the industry. To fill the widely varying needs of our customers, we manufacture a complete line of timers in the four broad classifications illustrated above: Time Delay Timers, Re-Cycling Timers, Interval Timers, and Running Time Meters. From these our timer engineers have developed 20 basic types which they have so far combined in over 1000 different ways. Therefore—many jobs that would seem to require a special timer, are in fact, a standard timer with us.

And our large stock assures you of rapid deliveries—even when we have to create a brand new timer for your special needs. So why not send us your specifications. You'll get a prompt reply and you may save yourself much lost motion.

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AFFILIATE—LINE ELECTRIC COMPANY

feed back a position signal to either an indicator or a servo system.—United Hydraulics, Inc., Dayton, Ohio.

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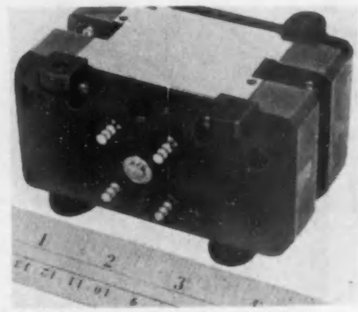


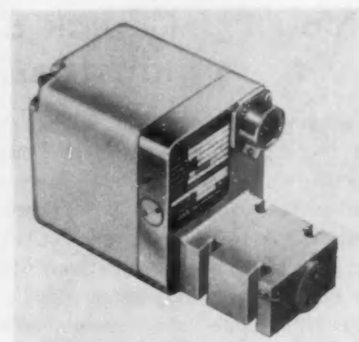
COMPACT TORQUE MOTOR

Featuring high performance at relatively low cost, this new torque motor will operate completely immersed in any mineral-based hydraulic field. Designed to actuate hydraulic servovalves and similar devices, it boasts the following

Characteristics:

Input power: 4 watts
Output force: ±15 lb at midposition
Output stroke: ±0.02 in., nominal
Hysteresis: 2 percent, nominal
Size: 4 in. by 3¼ in. by 2¼ in.
—American Measurement & Control, Inc., Waltham, Mass.

Circle No. 36 on reply card



FOR LOW FLOWS

Developed for aircraft and missile applications, the Series 5214 single-stage electrohydraulic servovalves combine high-speed response with a relatively low power output. Their simple direct drive and dry torque motor design provide exceptional reliability with flow outputs under 1 gpm. Mod-

els are available for operation at supply pressures up to 3,000 psi. Units have a natural frequency of 350 cps and a 90-deg phase lag at 350 cps. Internal leakage is less than 15 cu in. per min.—Lear, Inc., Elyria, Ohio.

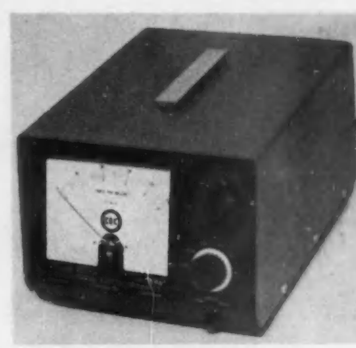
Circle No. 37 on reply card

PLUS. . . . .

(38) **Skyvalve, Inc.**, Syracuse, N. Y., is currently producing some 48 different **solenoid valves** for use in high-pressure hydraulic and pneumatic systems on aircraft, missiles, and rockets. . . . (39) A low-cost line of **solenoid valves** for general industrial applications has just been announced by **Jackes-Evans Mfg. Co.**, St. Louis, Mo.

Circle No. 38 or 39 on reply card

RESEARCH, TEST & DEVELOPMENT



MOISTURE MONITOR

The Type 26-302 Moisture Monitor, shown above, will measure water content in gaseous mixtures down to 10 ppm full scale, and permit precise meter readings over the range of 0 to 20,000 ppm by means of a six-position attenuator. Output can be telemetered to a remote recorder for monitoring or controlling such things as humidity in wind tunnels, dew point in furnaces, and atmospheres in driers. The unit operates on a 105-to-125-volt, 50- or 60-cycle supply, but can also be used with a battery pack when no electric power is available.—Consolidated Electrodynamics Corp., Pasadena, Calif.

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In research—meet a man who gets results . . .

Dr. Barkley, with 19 years experience in research and research management, directs and plans all activities listed at right—but still finds time for fishing and golfing only minutes from home. Dr. Barkley is one of the reasons our customers say, "At General Mills, we get results."

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Our research activities cover broad areas in physics, chemistry, mechanics, electronics and mathematics. Some of the studies representative of these activities are:

Solid state physics investigation
Special and ultra-pure materials
Ions in vacuum
Sputtering by bombardment
Electron physics
Surface electron microscopy
Surface phenomena
Optics
Particle mechanics
Lighter-than-air vehicle concepts
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Rheology
Physical Chemistry
Applications of plastics
Radiation research
Magnetic phenomena
Plasma dynamics
Ion dynamics and propulsion
Geophysics
High altitude physics
Physical instrumentation
Information theory

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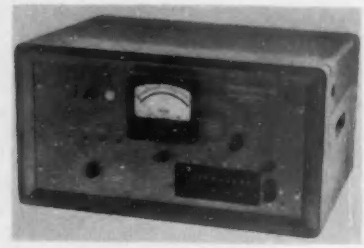
NEW PRODUCTS



COMPONENT TESTER

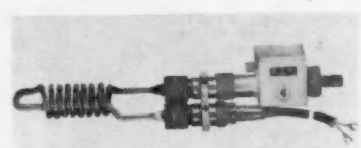
Pictured is the Model BT-1 test unit for back current, saturation, or reverse testing of germanium or silicon semiconductors. It features a mirror-back 1-percent meter in a fully protected electronic circuit, regulated power supplies, keyboard metering, and recorder output.

Characteristics:

Output voltages: four; 0-100, 0-1,000, and two 0-300 volts
Line and load regulation: within 0.1 percent
Ripple: less than 1 percent
Meter ranges: 0-1,000, 0-300, 0-100, 0-30, 0-10, and 0-3 volts, μa, or mμa

—Trans Electronics, Inc., Canoga Park, Calif.

Circle No. 41 on reply card



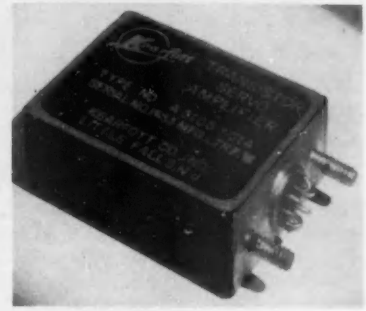
READABLE TO 0.01 DEG C

Sensitive to a few thousandths of a degree, this direct-setting thermoregulator simplifies high-precision temperature control. The device combines the displacement principle of the ultramicro buret with a glass spiral U-tube. A micrometer screw accurately measures the displacement of a stainless steel plunger entering an exact mass of mercury and operates a mechanical counter, which reads the exact temperature. A larger, secondary plunger adjusts the range of the instrument between minus 35 to plus 200 deg C in 100-deg intervals. Counter covers 100 deg C in 0.02-deg divisions. Readability is within 0.01 deg C and absolute accuracy within 0.1 deg C.—Emil Greiner Co., New York, N. Y.

Circle No. 42 on reply card

NEW PRODUCTS

COMPONENT PARTS



WEIGHS JUST 1½ OZ

Small, light, and rugged, the tiny transistorized servo amplifier pictured here can deliver up to 2.5 watts and drive a variety of servomotors. The unit is highly resistant to shock and vibration and so particularly suited to high-speed aircraft and missile applications. Suitable external resistors will vary the gain anywhere between 150 and 1,000. Power gain is 62 db, voltage gain 43.5 to 58 db, and gain stability within 2.5 db.—Kearfott Co., Inc., Clifton, N. J.

Circle No. 43 on reply card

TIME SAVING KIT

This new servo system construction kit, says the manufacturer, has several advantages over older methods. Chief among these is a 90-percent reduction in construction time and the finished system's adaptability as an operational unit. For typical application, see CtE, Feb. '58, p. 133.—Gap Instrument Corp., Freeport, N. Y.

Circle No. 44 on reply card

TOROIDAL TRANSFORMERS

Designed for transistorized dc-to-dc or dc-to-ac converters, a new line of toroidal transformers features power ratings to 120 watts, input voltages of

Just published – bobbin core guaranteed performance limits!

We have just published new data which will light the way to ease, sureness and accuracy for the designer who works with tape wound bobbin cores.

First—and this is a "first"—we have published *guaranteed* maximum and minimum performance limits for all of our bobbin cores. Computer-type designers who would like open-circuit characteristics, guaranteed core flux and guaranteed squareness will find them all here.

Second—and this too is a "first"—we have published the first fundamental data on characteristics of bobbin cores for circuit designers. Need core total flux characteristics as related to core material? Want switching time vs drive levels? How about typical spreads of core characteristics? It's all yours.

Third—and this too is a "first"—we automatically give you test data for prototype orders. With your prototype cores come open-circuit outputs, total flux, and squareness data. You get a basic understanding of the core's characteristics under specific test conditions. More important, when you re-order production quantities, you will be able to duplicate the core around which you designed your circuit.

Last—but still a "first"—to show that we manufacture as well as publish, we have designed the first bobbin core protective cap which will permit normal potting procedures for all sizes of steel and ceramic bobbins. Our "Poly Caps" have virtually no effect on dimensions—and will not soften or deform under manufacturing or operational temperatures. We'd like to show you samples.

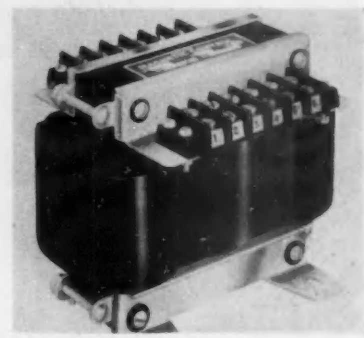
At what stage do you want to start? Whether it's design data, prototype data and cores, or production quantities of our "Performance-Guaranteed" bobbin cores—you can get what you need by writing Magnetics, Inc., Department CE-48, Butler, Pennsylvania.

MAGNETICS inc.

NEW PRODUCTS

6, 12, and 24 vdc, and output voltages to 600 volts. Basic power transistor switching transformers, designed for multiple-tap power transformers, are also available for transistors of different power ratings.—Polyphase Instrument Co., Bridgeport, Pa.

Circle No. 45 on reply card



CONTROL REACTORS

A complete line of control reactors for magnetic amplifiers includes 48 standard units covering from 15 to 450 watts. Sensitivities range from 1.5 to 3 ampere-turns in four separate series. Both 117-volt and 240-volt models are standard.—Chicago Magnetic Control, Chicago, Ill.

Circle No. 46 on reply card

PLUS. . . . .

(47) **Plug-in printed circuit bales** for logic systems are now available from **Skiatron Electronics & Television Corp.,** New York. . . . (48) Stainless steel construction with high nickel laminations provides extreme corrosion resistance in a new line of **synchros, resolvers, and linear transformers** recently announced by **Induction Motors Corp.,** Maywood, Calif. . . . (49) **Electro Measurements, Inc.,** Portland, Ore., is producing a compact, panel-mounted **ac voltage divider** with a linearity that rivals that of laboratory standards. . . . (50) New **equipment for breadboarding** and test of servo and instrument mechanisms has just been introduced by **Precision Mechanisms Corp.,** East Meadow, N. Y. . . . (51) Only **size-8 servomotor** capable of operating at 115 volts is now offered by **Helipot Corp.,** Newport Beach, Calif.

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37	38	39	40	41	42	43	44	45
46	47	48	49	50	51	52	53	54
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64	65	66	67	68	69	70	71	72
73	74	75	76	77	78	79	80	81
82	83	84	85	86	87	88	89	90
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145	146	147	148	149	150	151	152	153

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(100) OIL MOTORS & PUMPS. Tuthill Pump Co. Catalog 11, 4 pp. Covers the Powermax series of hydraulic pumps (capacities of from 1.2 to 14.2 gpm; continuous service pressures to 1,500 psi; speeds to 3,600 rpm) and hydraulic motors (continuous pressures to 1,500 psi). Includes performance curves.

(101) VIBRATION. Consolidated Electrodynamics Corp. Instrumentation Newsletter, 5 pp. Two things are of interest here: the newsletter itself and the particular contents of the one at hand (No. 5 on vibration instrumentation). Last page tells how you can get on the CEC mailing list; first four pages show, by means of an illuminating discussion of vibration instrumentation, why this might be wise.

(102) MINIATURE COMPONENTS. Grayhill, Inc. Condensed Catalog M-202, 8 pp. The switches on display here—it is essentially a switch catalog—include the pushbutton, rotary tap, and power tap variety. Information includes characteristics, dimensions, and what appear to be actual-size photos. Test clip adapters and binding posts also described.

(103) MAGNETIC MODULATORS. General Magnetics, Inc. Bulletin, 4 pp. Here's really a lot of information about two miniaturized input units and a magnetic thermocouple converter. They're made especially for printed circuit wafer structures and circuit assemblies.

(104) BREADBOARD PARTS. Beckman/Helipot Corp. Catalog 575, 24 pp. These standard electromechanical parts include shaft couplings, limit stops, dial assemblies, gears, differentials, and magnetic clutches. Parts are described in the order they would be used in breadboarding. Photos and drawings fill out coverage.

(105) MERCURY SWITCHES. Gardos Corp. Bulletin, 8 pp. Twenty-one switches get the full treatment here: type, switching action, differential angle, load, amperage with locked rotor rotating, height, length, diameter, etc. Attention also given to terminals, lead wires, and mounting clips.

(106) PYROMETER SUPPLIES. Minneapolis-Honeywell Regulator Co. Buyers' Guide G100-8, 54 pp. This big bulletin covers Honeywell's complete line of thermocouple accessories for measuring temperature. Some of the thermocouple categories: base-metal, small-mass, noble-metal, special-purpose. Catalog also includes sections on components, mounting attachments, and charts and inks.

(107) COMBUSTION CONTROL. The Hays Corp. Publication 57-1088-239, 12 pp. Heart of this bulletin is a pair of boiler-control systems (metering or position control) for single-burner boilers for gas, oil, or alternate firing. Data especially heavy on program control equipment for startup, normal operation, operating shut-down, and emergency shut-down.

(108) DYNAMIC MEASUREMENT. Columbia Research Laboratories. Bulletin, 32 pp. Describes a line of more than 40 accelerometers, high-temperature strain gages, and associated equipment. Drawings, tables, and graphs present specs and performance characteristics in terms of sensitivities, natural frequencies, acceleration, and temperature ranges.

(109) PHOTOELECTRIC CELLS. Vickers, Inc. Bulletin EPD 3216-1, 12 pp. Describes a line of self-generating, barrier layer p-e cells along the lines of construction details, performance characteristics, power output, circuits, and suggested appli-

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cations. Among the last: electrical and chemical engineering, chemistry, photometry, photography, and medicine.

(110) CONTINUOUS TITRATION. Milton Roy Co. Data Sheet A-58-2, 4 pp. Where control by pH, conductivity, or specific gravity is out of the question, says this bulletin, the solution may be titration. It then gives a complete description of the Dow-Hart Titrator, a Dow Chemical Co. development that uses several Milton Roy components.

(111) TWO MANOMETERS. Wallace & Tiernan, Inc. Bulletins TP-15-A-6 and TP-30-A-6, 4 pp. each. Deal with Type FA-129 (aneroid) for transducer calibration, altitude and wind-tunnel tests, and environmental test work, and Type FA-145 (dial) for dynamometer tests, pneumatic load cell indication, and leak tests on pressurized vessels, and as a Machmeter.

(112) INSTRUMENTING WATER TREATMENT. Fischer & Porter Co. Bulletin 90-130-25, 6 pp. F&P author Arthur L. Landesman, manager of the Pulp & Paper Dept. at Hatboro, Pa., tells how instrumentation of water and waste treatment improves efficiency, reduces manpower, and saves raw materials.

(113) FLOAT VALVES. Atlas Valve Co. Bulletin FV 4-58. One sheet. Describes two auxiliary-actuated float valves (types 214 and 216), single-seated, piston-operated units that control liquid levels to within 1-in. limits and provide tight closure for dead-end applications. Inlet pressure range: 15 to 150 psi.

(114) REMOTE CONTROL. Lear, Inc. Bulletin EM-302, 4 pp. Covers the Electrolink system for industrial automation. Ingredients: a combined controller-amplifier and a servo drive. Functional diagram shows how a manual movement is converted into an electrical error signal, whose polarity determines which of two magnetic powder clutches will be actuated in the servo drive.

(115) BUFFERS FOR STORAGE. Telemeter Magnetics, Inc. Bulletin, 4 pp. Tells about a series (1092) of reliable and flexible magnetic-core buffers for temporary or intermediate storage. These transistorized units give the necessary compatibility to heterogeneous digital systems. The series number comes from the number of characters able to be stored.

(116) COMPUTER-GRADE CAPACITORS. General Electric Co. Bulletin GEA-6819, 6 pp. Says anodes in these "super-pure" capacitors use 99.99 percent aluminum foil in every rating, thus assuring less high and low leakage currents, longer life. Ambient temperature range is minus 20 to plus 65 deg C. Tables and graphs cover materials, performance specifications, etc.

(117) CHOPPERS. James Vibrapowr Co. General Catalog F-2133, 4 pp. First page, characteristics; second and third, a chart giving tabulated information about 76 models, and the fourth page, diagrams of 14 basic designs. Among the specific areas referred to: maximum contract rating, frequency, residual and thermal noise, high and low temperature operation.

(118) MAGNETIC CORE TESTER. Rese Engineering, Inc. Bulletin 57-G, 4 pp. Describes a modular, current pulse generator (pulses up to 2 amp) that delivers programmed pulse chains in a periodically repeated, basic eight-step pattern, for laboratory analysis and production testing of magnetic materials.

(119) RELAYS. Filtors, Inc. Catalog, 20 pp. This three-color job covers a complete line of hermetically sealed micro and subminiature relays. Presentation is by way of specifications, operational data, and illustrations and detailed drawings.

(120) THERMOMETERS. Minneapolis-Honeywell Regulator Co. Catalog C60-2, 56 pp. This Industrial Div. publication deals with a complete line of Brown thermometers—indicators, recorders, transmitters, and electric or pneumatic controllers. Thermal systems also described. Limits are minus 125 to plus 1,000 deg F.

(121) VALVE TOME. Numatics, Inc. General catalog, 108 pp. We haven't seen a copy of this, but it sounds big. Application and operational data, specs, dimensional drawings, etc., presented for four-way valves and manifolds, two- and three-way line valves, manual valves and manifolds, and pilot and special valves. Individual sections are tabbed and indexed.

(122) RELAYS. Comar Electric Co. Catalog 58, 36 pp. Among the types of relays covered: general-purpose ac, general-purpose dc, plug-in, printed-circuit, telephone. Total: 33. Catalog opens with some data on contact ratings and coils, closes with more on solenoids, switch assemblies.

(123) TIPS ON RELAYS. North Electric Co. Bulletin, 6 pp. Points out features to look for when selecting relays. These include the sound of the relay, the type of pivots used, and the effect of residual air gap reduction.

(124) ELECTROHYDRAULIC CONTROL. Sanders Associates, Inc. Bulletin No. 809, 4 pp. Illustrates a complete line of electrohydraulic servovalves and a valve production test stand. Added feature of the bulletin is a checklist of applications developed from experience in both component and systems engineering.

(125) CURRENT PULSE SOURCE. Rese Engineering, Inc. Bulletin 57-C, 2 pp. Cites design features and lists specifications of the Model 1050 high-impedance current pulse generator, a unit capable of current outputs up to 3 amp.

(126) THERMISTOR PROBES. Fenwal Electronics, Inc. Bulletin EM-13, 4 pp. Deals with nine specially designed thermistor probe assemblies. Identifies each by its most common application and provides dimensions and mounting data.

APPLICATION LITERATURE

NOTE: To receive any of the following items, the reader should write directly to the manufacturer at the address given.

POCKET-SIZED GLOSSARY. Trans-Sonics, Inc., Burlington, Mass. Intended as an up-to-date reference guide, this handy (only 4½ by 6 in.) 20-page glossary contains almost 100 definitions of terms most frequently used in the field of tempera-


PLATINUM RESISTANCE THERMOMETER

PRESSURE ALTITUDE

(see STANDARD ATMOSPHERE)

PRESSURE POTENTIOMETER

14

ture and pressure instrumentation. Many of them are illustrated with drawings or graphs, as a typical page, above, shows. Although the list is by no means exhaustive and no attempt was made to include ordinary dictionary definitions, this little booklet should prove quite useful to engineers in the missile, aircraft, or process industries.

SUGAR PLANT CONTROLS. Fischer & Porter Co., 550 Jacksonville Rd., Hatboro, Pa. Catalog 90-260-10, a 12-page illustrated bulletin, covers nearly every phase of instrumentation for the sugar cane industry. While many of the processes described are peculiar to this one industry, the equipment and control systems

should be of interest to all engineers concerned with wet process control. Page 3, shown here, deals with the control of an automatic liming process in which pH, retention time, and the lime-to-juice ratio must all be controlled. Other interesting examples: the instrumentation of a milling tandem, a sugar evaporator, and a cane-seedling treating bath.

ABSTRACTS

Batch Process Control—I

From "Automatic Controls for Batch Processing in the Chemical Industry" by K. Hengst. Abstract prepared by Sigmund Rappaport, project supervisor at Ford Instrument Co. and adjunct professor of kinematics, Brooklyn Polytechnic Institute. From an article in the German publication REGELUNGS-TECHNIC, VOL. 6, No. 2, 1958. Subsequent issues of CONTROL ENGINEERING will carry two more abstracts by Rappaport of other articles in the same issue. At present we have no information about the availability of complete English translations.

Discontinuous processes in the chemical industry offer some challenging problems in automatic control. Quality and uniformity of product depend chiefly on rigorous adherence to a given set of process conditions. Because one faulty link in the control chain could very well ruin an expensive product, manual override must be possible at all times. This presupposes highly skilled personnel.

Pressure and temperature are still the principal controlled variables in a reaction process. Pressure control in batch processes differs very little from pressure control in continuous processes. In the case of temperature control, however, several factors peculiar to batch processes affect performance uniquely. One of these is the time delay associated with large reaction vessels. Another is the large temperature difference that can exist within a tank when the product cannot be stirred. And a third is the sensitivity of the product to local overheating or undercooling.

The following discussion deals with four major control problems in batch processing and provides a typical solution to each.

Charge of raw product

Today the preparation and charge of raw product is still largely a manual operation, despite the fact that automatic control will not only provide more uniform mixing ratios but will safeguard the charging sequence. Figure 1 shows a typical arrangement for automatically charging a reaction tank. First a metering pump loads the tank with a predetermined volume of water. A vacuum then evacuates the gas space in the tank and nitrogen is fed in under pressure. The tank is then evacuated again, and more nitrogen is added. A third evacuation readies the tank for the raw product charge. During this time, the raw product is automatically weighed. A control signal starts the raw product on its way to the scale, and a photocell stops it when the desired amount is reached.

Start of the reaction

Starting the reaction and heating the charge to the correct reaction temperature are problems peculiar to the batch process. Figure 2A shows a reaction tank with single temperature control. The temperature signal from inside the tank is transmitted to two control valves that control the flow of both steam and water in the heating circuit.

First the temperature control is set at the reaction temperature. Initially, this demands a high steam-water ratio.

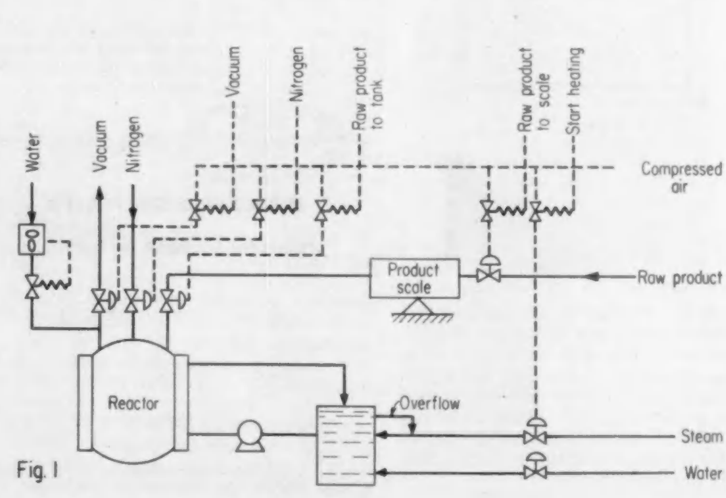


Fig. 1

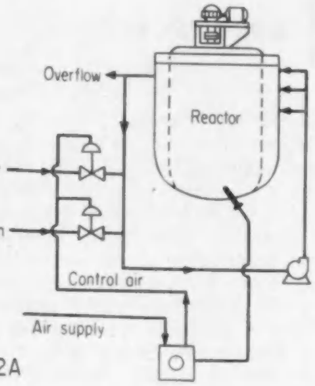


Fig. 2A

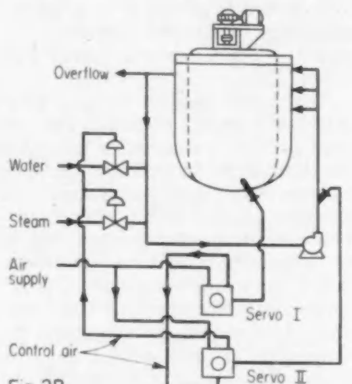


Fig. 2B

Satisfactory operation results only when a proportional or proportional-plus-rate type of controller is used. A control containing an integral operator may not be able to deal with the problem of overshoot.

The graphs in Figures 3A and 3B, based on the system of Figure 2A, illustrate this point. Figure 3A represents temperature response when reset action is added to the controller, Figure 3B response with proportional plus rate action alone. The disadvan-

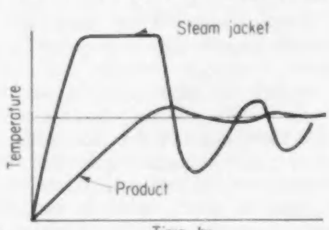


Fig. 3A

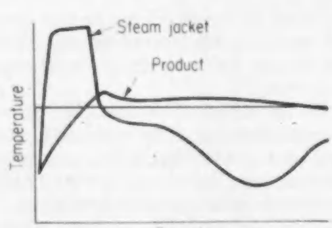


Fig. 3B

tage of single-temperature control may be overcome by using cascade control and adjusting desired values according to a preset program. The schematic for such a system is shown in Figure 2B. Here, Servo II controls the temperature in the steam jacket, and Servo I, whose sensing element is in the tank, adjusts the setting of Servo II. Response curves for this type of arrangement clearly show the superiority of cascade control. Product temperature is governed by a proportional-type controller adjustable to within 4 deg C by the second controller.

At the start, product temperature is outside the control range and the heat circuit set at maximum. During the last third of the temperature rise Servo I comes into action and reduces the set-point of the jacket temperature. This permits product temperature to be approached without overshoot. When the reaction has started, jacket temperature is abruptly lowered and the system cooled. Subsequently, the temperature is again raised from 70 to 80 deg C by means of a programming device. During this period, Servo I remains within the control range.

In summary, cascade control:

- permits close control of the limits of the auxiliary control value
- provides a fast control circuit that eliminates the influence of short disturbances, thus helping to maintain linearity
- smooths out input variations
- improves performance by virtue of a shorter time delay in the auxiliary control circuit

Reaction periods

Reaction periods in most batch processes are usually at constant temperature and/or pressure, and programmed in advance. But certain characteristics of the charge change with time; e.g., in the beginning of polymerization processes, thermal conductivity of the charge is comparable to that of water, whereas the end product is often a good insulator.

Discharge of finished product

Most of the problems in this phase of batching operations do not differ materially from those in continuous processes.

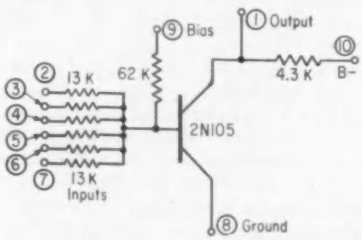
In conclusion, it can be shown graphically that fully automatic control of a batch process will very often provide the most satisfactory results under the most difficult conditions.

Sigmund Rappaport

Small Computer Controller

From "A Transistorized Digital Control System With Precision Indication of the Controlled Variable" by W. M. Kaufman and T. A. Jeeves, both of Westinghouse Research Labs. AIEE Paper No. CP 58-232, presented at the AIEE Winter General Meeting, New York, Feb. 2-7, 1958.

The authors describe a flexible digital control computer designed to accept feedback data in the form of variable frequency, provide dc output signals to actuate control operations, and give a numerical display of the controlled variable. Logic circuitry consists entirely of transistor NOR



elements (the figure above shows a schematic diagram of one of them). Individually, they provide an output signal only when no signals are present at any of their input terminals; combined, any of the normal logical functions can be obtained.

On Switching Circuits

From "Non-Binary Switching Theory" by Oscar Lowenschuss of Sperry Gyroscope Co. Paper No. 49.3 presented at the IRE National Convention, New York, March 24-27, 1958.

Switching devices with more than two distinct states can be used to design nonbinary switching circuits, and hence nonbinary digital computers. A mathematical model (but not a Boolean one) must be used.

Special algebras permit circuit design and minimization in terms of available hardware. Such devices and their algebras require functional completeness, i.e., the ability to represent in closed form any function of several variables gives by means of a truth table. Methods exist for proving the functional completeness of these algebras.

An "expansion theorem", to indicate how any given function of m variables can be expressed in terms of functions of $m-1$ variables, can be found for any functionally complete algebra that possesses an identity element.

NEW BOOKS

Notes on Computing

MODERN COMPUTING METHODS. *Notes on Applied Science No. 16, Dept. of Scientific & Industrial Research. 130 pp. Published by Philosophical Library, Inc., New York. 1958. $8.75.*

Based on lectures delivered by members of the British National Physics Laboratory, this book offers a brief account of computing techniques in use today, with particular emphasis on the numerical mathematics involved.

The first four chapters discuss "algebraic" problems. Chapter 3 considers the determination of real and complex roots of polynomial equations, while Chapters 1, 2, and 4 deal with the basic problems of "linear algebra", the solution of simultaneous linear algebraic equations, the inversion of matrices, and the determination of their latent roots and vectors. Methods included apply to desk machines as well as to high-speed digital equipment.

Chapters 5 through 9 cover analysis. Chapter 5 introduces the theory of finite differences used in Chapters 6 and 7 to solve ordinary differential equations of either boundary-value or initial-value types. Chapter 8 considers the solution of hyperbolic differential equations by "characteristics", and Chapter 9 discusses various methods of solving parabolic and elliptic partial differential equations.

Many problems in linear algebra, and the simultaneous finite-difference equations, linear or nonlinear (used to represent the solution of ordinary or partial differential equations), are often conveniently solved by the methods of successive approximation. These so-called indirect methods are described in Chapter 10.

Chapter 11 discusses problems in the construction of mathematical tables and Chapter 12 shows why a variety of techniques must be used in solving a given problem.

Appendix 1 compensates for the lack of detail in certain sections by presenting a fairly comprehensive bibliography of the most useful books and papers on numerical analysis. Appendix 2 briefly describes the DEUCE high-speed digital machine and its application to a set of simultaneous nonlinear differential equations.

The third and last appendix contains a few notes on the operation and application of a typical mechanical differential analyzer. A second bibliography, on differential analyzers only, follows this short discussion.

WHAT'S AVAILABLE IN REPRINTS

The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Some reprints are individual articles, while others are "packages"—several articles published over a period of time that logically supplement one another in the coverage of a specific phase of the control field. Any reprint can be obtained at the nominal cost listed below by filling in the order form and sending it, together with remittance, to Readers Service Dept. Quantity rates will be quoted on request.

What's Available in Flowmeters, 24 pp. A comprehensive coverage of positive displacement, velocity, and mass flowmeters, including characteristics, applications, and typical manufacturers; plus details of a special drag disc meter. 50 cents.

Selecting and Applying Control Timers, 24 pp. A compilation of four articles including a tabular description of timer functional parts, criteria for selecting and applying control timers, a tabular listing of available timer types and their characteristics, and techniques for custom-designing controllers for time-based routines. 50 cents.

What the Control Engineer Should Know About Reliability, April 1958, 8 pp. Not intended as a comprehensive treatise, but rather as a guide to aim the control engineer in the right direction, this staff-written article discusses the new concept of systems effectiveness, and briefly covers techniques for measuring reliability, predicting reliability, improving reliability, and costing reliability. Up to date reference sources are listed. 20 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems, 72 pp. This complete series covers 31 domestic and foreign systems. Detailed operational and performance characteristics of each system are discussed. Individual parts of series are also available as listed below. $1.25.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—III, March 1958, 16 pp. Includes detailed descriptions of nine machine tool control systems. 40 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—II, February 1958, 24 pp. Includes detailed descriptions of ten machine tool control systems. 50 cents.

Survey of Numerically-Controlled Point-to-Point Positioning Systems—I, January 1958, 32 pp. Includes detailed descriptions of twelve machine tool control systems. 60 cents.

Ready Reference Data Files, 24 pp. A must for every control engineer's library. Includes the first 12 data files published in Control Engineering—a diversity of topics, from system reliability through the cost of industrial temperature-measuring systems. Each one gives a method of solving a particular problem. 50 cents.

Servo Modulators—Their Application, Characteristics, and Availability, 36 pp. A group of four integrated articles covering all phases of electromechanical, electronic, solid-state, and magnetic modulators. Typical circuit diagrams, characteristics, and applications are given for each type, plus an 84-item bibliography and tables listing commercial units. 65 cents.

The Use of Digital Computers in Science, in Business, and in Control, 112 pp. A collection of 14 articles published over a period of two years as the Digital Application Series. Prominent authorities cover the application, programming, overall system design, and commercial availability of digital computers in all phases of business, industry, and the military. $3.

Analysis Instrumentation – II – Refractometers, Infrared Analyzers, Photometric Analyzers, Colorimetry, 32 pp. This includes the second group of four articles of the Analysis Series. 60 cents.

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Basic Data on Process Control, 24 pp. A grouping of five articles on flow-process control, including: Basic Concepts of Feedback Control, Selecting Loops for Critical Control, Direct or Reverse Controller Actions, Modifying Valve Characteristics to Fit the Process, and Using Capacitance for Accurate Level Measurement. Practical information for every process control engineer. 50 cents.

How to Simulate Dead Time, 6 pp.

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WHAT'S AHEAD: MEETINGS

JULY

1958 Gordon Research Conference on Instrumentation, Colby Junior College, New London, N. H. July 28-Aug. 1

AUGUST

American Institute of Electrical Engineers, 1958 Special Technical Conference on Nonlinear Magnetics and Magnetic Amplifiers, Hotel Statler, Los Angeles, Calif. Aug. 6-8

American Institute of Electrical Engineers, Pacific General Meeting, Sacramento, Calif. Aug. 19-22

SEPTEMBER

Association Internationale Pour Le Calcal Analogue, Second International Analog Computation Meeting, Strasbourg, France Sept. 1-9

International Association for Cybernetics, Second International Congress on Cybernetics, Namur, Belgium Sept. 3-10

American Institute of Electrical Engineers, Power Industry Computer Application Conference, King Edward Hotel, Toronto, Canada Sept. 15-17

Instrument Society of America, Instrument-Automation Conference and Exhibit, Convention Hall, Philadelphia, Pa. Sept. 15-19

Association of Iron & Steel Engineers, 1958 Iron & Steel Exposition and Convention, Auditorium, Cleveland. Sept. 23-26

Institute of Radio Engineers, Seventh Annual Symposium on Industrial Electronics, Rackham Memorial Auditorium, Detroit, Mich. Sept. 24-25

OCTOBER

National Electronics Conference, sponsored by IRE, AIEE, Hotel Sherman, Chicago, Ill. Oct. 13-15

American Institute of Electrical Engineers, Machine Tool Conference, Statler Hotel, Hartford, Conn. Oct. 13-15

Society of Industrial Packaging & Material Handling Engineers, Annual Exposition, Competition and Short Course, Chicago, Ill. Oct. 14-16

National Conference on Industrial Hydraulics, sponsored by Armour Research Foundation, Hotel Sherman, Chicago, Ill. Oct. 16-17

REPRINTS

Three tricky techniques for simulating dead time or transport lag. One's electronic, another is pneumatic-mechanical, and the third uses magnetic tape. A useful reference source for control engineers concerned with process simulation. 15 cents.

Transistor and Thyratron Power Amplifiers, 28 pp. These three articles were prompted by the increasing control application of transistors as low-power amplifiers and thyratrons as high-power amplifiers. In each case the emphasis is on practical application, circuit design, system stabilization, etc. 50 cents.

Static Switching Devices—New Tools for Industrial Control, May 1957. 28 pp. An independent consultant analyzes the complete field of industrial static-switching systems. Starting off with a review of basic switching logic, he covers circuit characteristics of the fundamental devices, commercially-available systems, actual applications, etc. 50 cents.

A Functional Analysis of Automatic Logging Systems, February 1956, 16 pp. An examination of the various techniques and equipment used in performing the eight functions in a generalized automatic logging system: transducing, scale-factor correction and linearizing, derivation of quantities, scanning, analog-to-digital conversion, programming and control, alarm, and recording or logging. 50 cents.

Planning Programs for World Meetings

IFAC plots an ambitious technical program for the first world control congress, scheduled for Moscow in 1960.

Another important notch in international control was cut at a spring meeting of the International Federation of Automatic Control (IFAC) in Zurich. Meeting as guests of the Swiss Society of Automatics, IFAC's council and advisory group laid out plans for technical programs to be held through 1960. The plans include participation in the 1958 meeting of the Belgian Institute of Regulation & Automatic Control and the 1959 annual September meeting of ISA. But chief topic at the Zurich meeting was the program for the 1960 Control Congress in Moscow.

With the approval of IFAC, Russian hosts for the 1960 meeting have prepared an ambitious agenda. It covers three main areas. Papers on automatic control theory will cover discrete data systems, continuous data systems, systems using computing devices, optimalizing, multivariable systems, systems including a human operator, information theory, switching theory, stochastic processes, and simulators.

Papers on components and measurements, the Russians said, will be sought covering the design and performance of transducers, amplifiers, computers, logic elements, regulators, telemetry, final control elements, characteristics of components, methods of dynamic testing, and reliability.

The Russians suggested that each paper on application pertain to a particular industry or type of controlled equipment. Typical examples: electrical machines, power systems, petroleum processing, chemcial processing, ore refining, metal production, metalworking, transportation, materials handling, nuclear reactors, and heating and air conditioning.

• **IFAC's trio**—The three-way plan for the Moscow meeting reflects the three-pronged organization of IFAC's technical committees: 1) automatic control theory, 2) components and measurements, and 3) applications. Individuals will participate in IFAC technical meetings through committee activity, presentation of papers, and subscription to a quarterly bulletin that will report on meetings held around the world.

In the U. S., technical papers for the Moscow meeting are being encouraged by the American Automatic Control Council (AACC). Chairman of the AACC papers-review committee, E. M. Grabbe, Ramo-Wooldridge Corp., urges U. S. engineers to submit such technical papers to him or to the technical committee chairmen. These are:

• Automatic control theory—John Truxal, EE Dept., Brooklyn Polytech, Brooklyn, N. Y.

• Components and measurements—Jack Ward, Instrument Dept., Engineering Services Div., E. I. du Pont de Nemours & Co., Inc., Louviers Building, Newark, Del.

• Industry applications — D. M. Boyd, Universal Oil Products, Des Plaines, Ill.

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by
Roy E. Marquardt,
President

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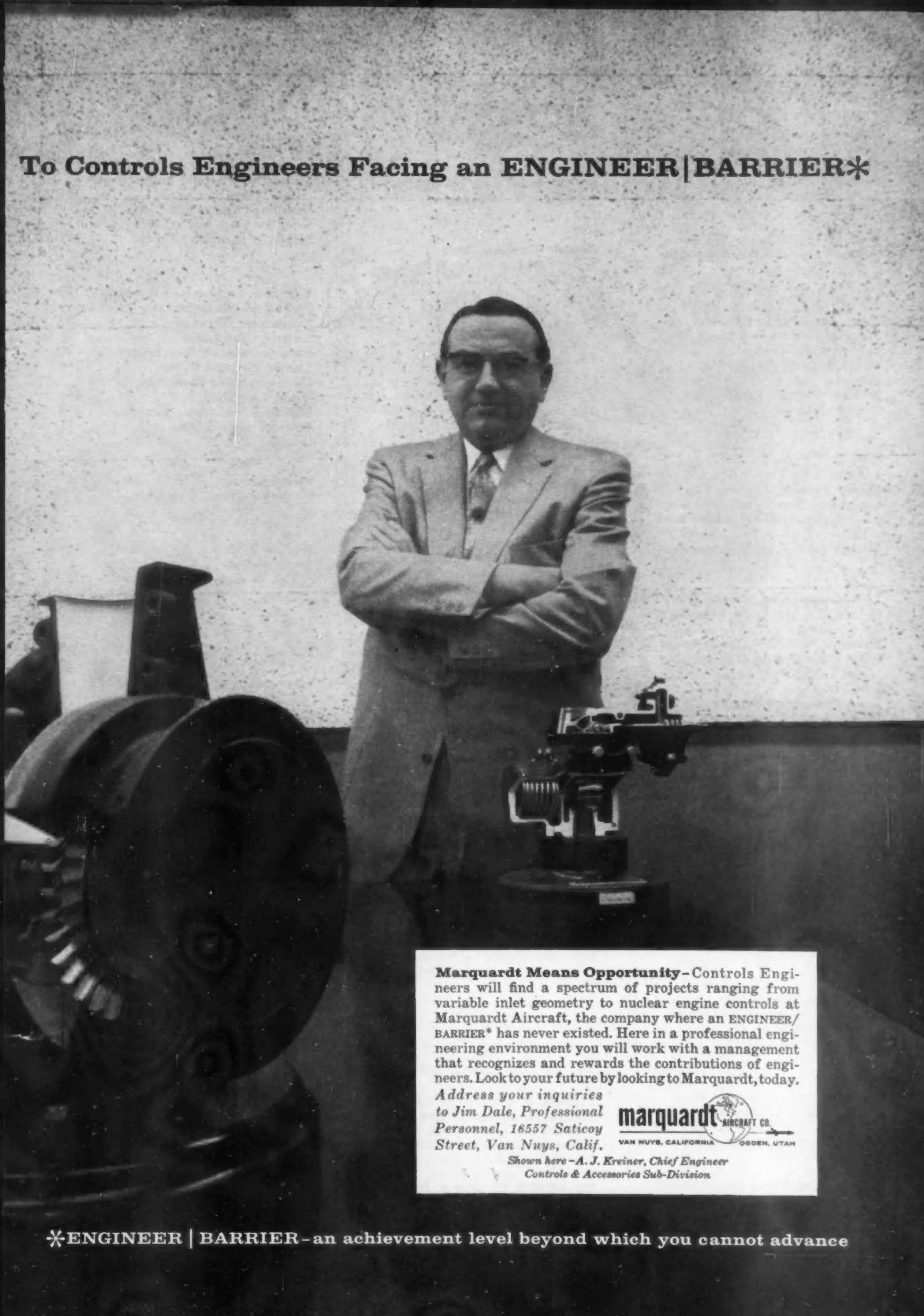
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